TOLEDO PUBLIC LIBRARY
TECHNICAL DEPARTMENT
MAR 22 1933

ILLUMINATING ENGINEER

XVI | March 1933 | Price 9d.

INDEX

	PAGE
EDITORIAL NOTES :—	
Everyday Photometry with Photo-electric Cells ...	61
TRANSACTIONS of the Illuminating Engineering Society (Founded in London, 1909; Incorporated 1930) :—	
Nominations for Officers and Members of Council...	62
Account of Meeting on February 14th, 1933	63
Everyday Photometry with Photo-electric Cells, by J. W. T. Walsh...	64
(*Discussion*)	72
Account of Annual Dinner	73
The Effect of the Spectral Transmission of the Atmosphere upon Visibility by Artificial Light, by M. G. Bennett	75
A Long-range Telephotometer, by C. H. Silvester Evans...	80
LIGHTING LITERATURE	82
DIRECTORY OF LIGHTING EQUIPMENT	86

SAFETY FIRST
You cannot afford to take chances with public lighting. Be safe—use only lamps which give a consistently high performance, lamps made to the most exacting specification—Number B.S.S. 161/1932.
THE LIGHTING SERVICE BUREAU, 2, SAVOY HILL, LONDON, W.C.2.
COSMOS CRYSELCO
EDISWAN MAZDA
OSRAM SIEMENS
Electric Lamps

You can rely on GAS LIGHTING

Four-fifths of the street lighting in 318 towns and cities in England and Wales is by gas . . . . That means 13,341 miles of gas lighting . . . . 635,000 gas lamps. In the streets of London lighted by this Company there are 50,000 lamps alight for nearly 4,000 hours every year. The gas supply has never failed.

* * *

What famous motorists said after a recent comparative test:

That the even diffusion of light which the gas lamps shed was eminently suitable for motoring purposes;

That gas gave a clear line of vision for several hundred yards ahead;

That gas lighting was certainly more penetrating in foggy weather;

That gas lamps had a delightful open light which gave one complete confidence as one saw a clear run for a long distance ahead with no shadowy patches.

* * *

Gas lighting helps ventilation and gives a soft light which does not tire the eyes. That makes it particularly suitable for large buildings, such as churches, factories and halls. Gas can be conveniently lighted by distance control switches and also time controls. And it adds a healthy warmth.

* * *

We invite all those within our area to consult us on any question of gas lighting, whether it be the modernising of equipment or the fixing of new installations Do not hesitate to seek the services of the Gas Light & Coke Co.

THE GAS LIGHT & COKE COMPANY

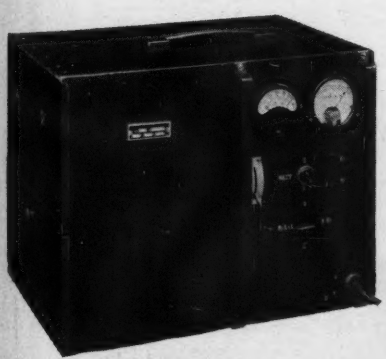
never lets London down

HEAD OFFICE: HORSEFERRY ROAD, WESTMINSTER, S.W.1

WHAT IS THE PHILIPS PHOTOMETER TEST?

The only test that proves the real efficiency of a lamp

When you pay for lamps, it is LIGHT you buy. You must have maximum light at lowest current consumption—highest efficiency, minimum cost. That is our claim for Philips Lamps. We can prove it by the Photometer test. The Philips Photometer will show you at a glance that Philips Lamps use their rated wattage to produce 100% good light. They solve your problem in the choice of lamps—it is the most convincing proof on which you can base your recommendation. Buy Philips Lamps, they are cheaper than so-called cheap lamps.



WRITE FOR A PHOTOMETER TEST

A test with the Philips Photometer will gladly be made at your premises. Write, stating your mains supply voltage, to the address below.

PHILIPS LAMPS ARE MADE IN ENGLAND

PHILIPS

ELECTRIC LAMPS

PHILIPS LAMPS LTD., PHILIPS HOUSE, 145, CHARING CROSS ROAD, LONDON, W.C.2.

Arks

What I think about the Bureau. 3.

LEON M. LION

famous theatrical producer, whose shows, *While Parents Sleep*, *A Cup of Happiness* and *The Holmeses of Baker Street* are now running in London, appreciates the value of good and reliable lighting.

"*Good lighting*" *says Leon M. Lion* "*is a most essential and vital point in the theatre which no management can afford to neglect. The Lighting Service Bureau has my fullest sympathy in the work that it is doing, and I recommend all those who are interested in good lighting to visit the demonstration rooms at the Bureau's head-quarters on Savoy Hill and see and hear for themselves how they can get the very best from their lighting schemes.*"

The Lighting Service Bureau is maintained by the makers of the following lamps:
COSMOS · CRYSELCO · EDISWAN · MAZDA · OSRAM · SIEMENS

NEW LIGHTING SCHEMES for London Underground Rlys. carried out with G.E.C. ELECTRICAL EQUIPMENT

Hyde Park Corner Station Booking Hall. Lighted by means of a luminous beam composed of G.E.C. rectangular Equiluxo dishes forming a continuous run round the entire area of the hall.

Turnpike Lane Station. A similar system of Escalator Approach lighting to that at Hyde Park Corner. G.E.C. bronze indirect Fittings with GECORAY reflectors are used for the Escalator lighting.

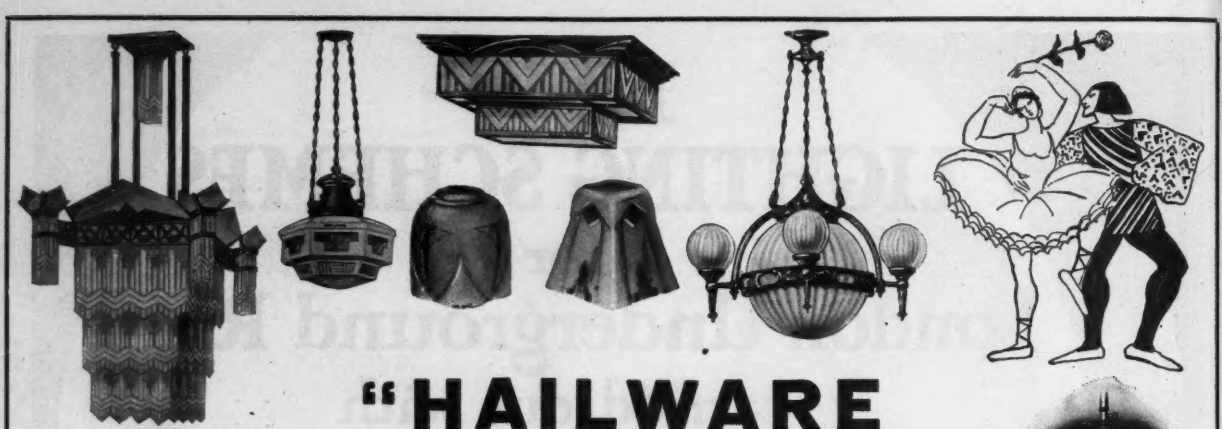
Fine examples of modern lighting distinguish the new stations and various of the existing stations which have been reconstructed in connection with new extensions of the London Underground Railways, including:

MANOR HOUSE STATION
TURNPIKE LANE „
WOOD GREEN „
BOUNDS GREEN „
ARNOS GROVE „
ACTON TOWN „
ALPERTON „
SUDBURY HILL „
HYDE PK. CORNER „
MARBLE ARCH „

G.E.C. Electrical Equipment predominates in these new lighting schemes, which employ:

G.E.C. ELECTRIC LIGHT FITTINGS AND ACCESSORIES.
OSRAM LAMPS.
MAGNET CONDUITS.
CLAUDEGEN NEON SIGNS.
G.E.C. DWARF CIRCUIT BREAKERS.
Etc., Etc.

Manufacturers:—
THE GENERAL ELECTRIC CO. LTD.
Head Office and Principal Showrooms:
Magnet House, Kingsway, London, W.C.2
Branches throughout Great Britain and in all principal markets of the World.



"HAILWARE IS THE BESTWARE"!

Its charm and beauty give
Joy, Happiness and Comfort.

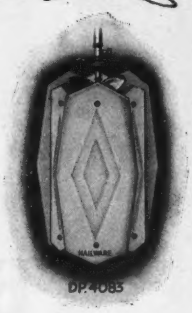
Sole Makers:

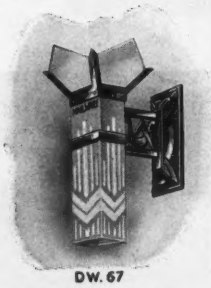
Hailwood & Ackroyd Ltd.

Beacon Works, MORLEY, LEEDS

Branches and Showrooms:

71/75, New Oxford St., London, W.C.1
314a, St. Vincent St., Glasgow, C. 3
28, High St., Birmingham





TYPE 3A/UNI
GAS CONTROLLER
15 DAY RUN

35/42 day run to order.
For "Square" Lanterns.

Automatic lighting

We offer a complete automatic lighting service, embracing both gas controllers and electric time switches.

Careful thought and experience in design, the best of British workmanship and materials, allied to the most up-to-date production and inspection methods, result in the utmost efficiency from Newbridge auto-lighters.

Many thousands are installed in all parts of the world, and satisfied users will gladly testify to the excellent results achieved.

Save the capital cost of converting indoor lighting to electricity by installing
NEWBRIDGE
Positive Distance
GAS SWITCHES.

Write for details.

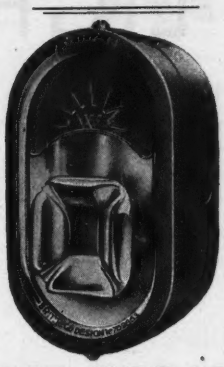
NEWBRIDGE

GAS CONTROLLERS
ELECTRIC TIME SWITCHES
They sell because they excel

Let us submit samples for test under actual working conditions, together with quotation and catalogue.

THE HORSTMANN GEAR COMPANY LTD., Newbridge Works, BATH

"ILLUMINATING" ECONOMY



"THE WIGAN" PRESSED STEEL PRISMATIC FITTING

ENSURES

Maximum Illumination Efficiency at a very competitive price.

Send for further particulars or sample (sale or return) to :—

HEYES & Co. LTD. WIGAN

PUBLISHED BY PITMAN'S

THE ELECTRIC WIRING OF BUILDINGS

By F. C. RAPHAEL, M.I.E.E.

This book is of immense value in the preparation of estimates for electric wiring installations, in the planning of work, and when the actual job is in progress. It provides indispensable and readily available information on the technical details of lay-out, the choice of switches, and the various systems of wiring, together with hints on the selection and use of auxiliary materials and accessories for every purpose. It is a valuable work of reference for the contractor, the wireman, foreman and electrical engineer.

268 pp. **10/6** net. Illustrated

Write for a complete list of Pitman's Technical Books, post free on request.

SIR ISAAC PITMAN & SONS LTD.

PARKER ST., KINGSWAY, LONDON, W.C.2

Purveyors of Electric Lamps By Appointment

Manufacturers and Purveyors of Electric Lamps By Appointment

EDISWAN

The name that means 'EXCELLENCE'

DEFINITE POINTS OF SUPERIORITY

THE SILVER DOME—*gives increased efficiency and greater lighting intensity on the display.*

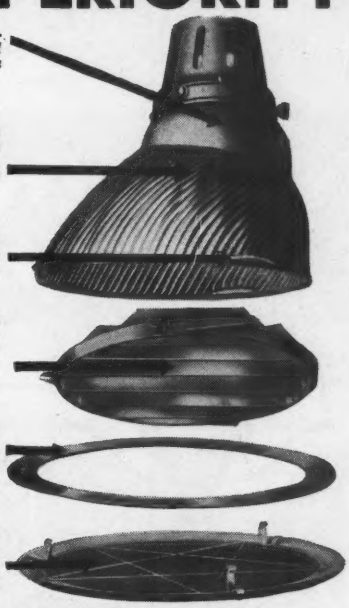
THE SILVERTONE BACKING—*protects the silvering. It cannot crack, peel or blister. Five years guarantee.*

THE "DIMPLES"—*which enable the accessories to be instantly snapped into position*

THE ANTI-GLARE SHIELD—*which snaps into the "dimples" and prevents side glare in island and corner windows.*

THE CEILING FLANGE—*for neat flush mounting of reflectors into ceiling. The opening required is circular.*

THE COLOUR SCREEN—*Snaps into the "dimples" and is designed for the quick and easy changing of four different coloured gelatines.*



X-Ray

SILVER DOME REFLECTORS

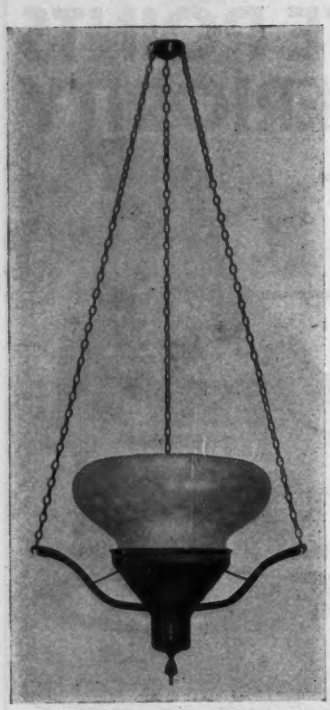
Every phase of shop-window and showcase lighting is covered by an appropriately designed X-Ray Reflector. Ediswan Lighting Engineers are always ready to collaborate with consultant and contractor in the planning of lighting schemes, free and without obligation.

Made in GREAT BRITAIN

The Edison Swan Electric Co. Ltd 155 Charing Cross Road, London, W.C.2.

Bring your lighting problems to EDISWAN

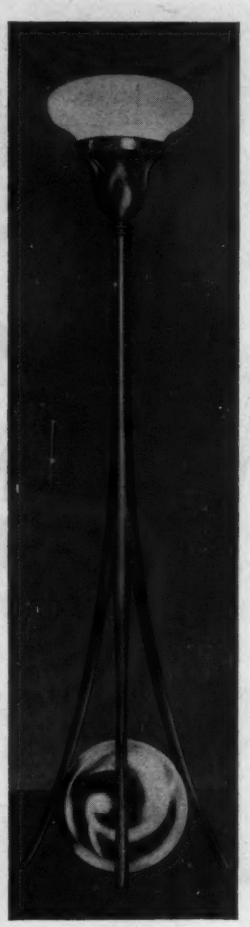
L.A.160

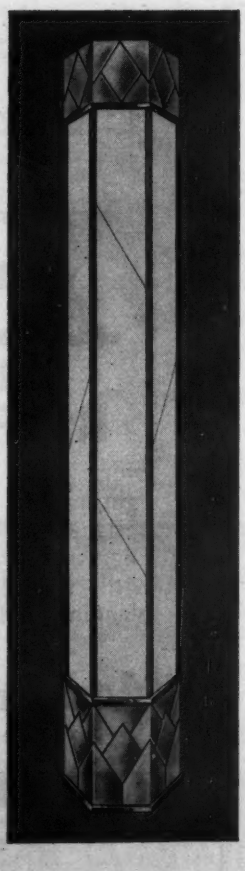


The G.V.D. Unit disperses its light at all angles, particularly in a LATERAL direction. Shadows, pools of light above or below the fitting and glare are eliminated. It makes possible uniform and economical lighting from a minimum number of points.

The above illustrations show three applications of the G.V.D. Unit, which is adaptable to every type of Pendant, Bracket and Standard for direct or indirect lighting — Pearl or Sunlight.

ON RIGHT—a Pillar, each of the six panels measuring 8ft. × 7ins. Uniformly lighted on all sides by one 200-watt bulb.





Controlled LIGHT

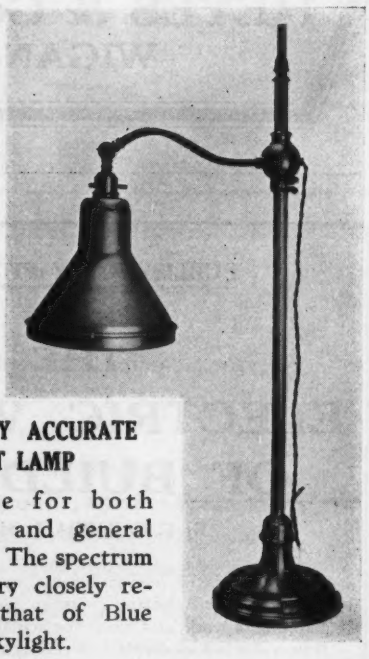
THE revolutionary G.V.D. System has aroused considerable interest.

Effecting REMARKABLE ECONOMIES both in installation and maintenance costs, it offers immense possibilities in every class of illumination.

The G.V.D. UNIT is adaptable to all forms of Pendant, Bracket, and Standard Lighting, either direct or indirect.

The G.V.D. ONE-BULB PRINCIPLE as applied to Laylights, Cornice and Pillar Lighting reduces costs to a very moderate figure, eliminates special provision for ventilation, and necessitates only 12 inches of ceiling depth.

Entirely **BRITISH** Invention— Capital— Manufacture



A REALLY ACCURATE DAYLIGHT LAMP

Suitable for both technical and general lighting. The spectrum curve very closely resembles that of Blue North Skylight.

NOW READY—A complete Catalogue giving interesting technical information and particulars of models is now available.

PLEASE PHONE or WRITE for a copy, or call for a demonstration.

G.V.D. ILLUMINATORS

(G. V. DOWNER)

ALDWYCH HOUSE, ALDWYCH
LONDON, W.C.2

'Phone : Holborn 8879 *'Grams : Gevedi, Estrand, London*

The latest arrival!

HOUSEWIVES ARE DELIGHTED with the latest British triumph in oven ware. Fashioned from pure fused silica, Vitreosil Dishes have all the amazing heat-resisting nature of Vitreosil Gas Globes combined with the pearly lustre of the finest porcelain.

Brought to table in its neat chromium-plated stand, a Vitreosil Dish presents an extremely stylish appearance which appeals to persons of modern taste.

Made in three sizes—	1 pint	1½ pints	2 pints
Retailing at	5/-	6/-	7/6

Chromium-plated Stands, Pattern A or B, retail at 1/9 each. (The top stand shown is Pattern A, the two lower stands are Pattern B.)

SPECIAL GIFT SET.—An Ideal Wedding or Birthday Present—consists of One of each size Dish and Pattern B Stand securely packed in decorative box ready for post. Retail 21/-.

For Trade Terms write the Sole Manufacturers:

THE THERMAL SYNDICATE LTD.
VITREOSIL WORKS, WALLSEND-ON-TYNE
London Depot: THERMAL HOUSE, Old Pye Street, S.W.1

VITREOSIL COOKING WARE
FLAME-PROOF LUSTRE

SIMPLEX OR *Credalux*
ELECTRIC LIGHTING EQUIPMENT

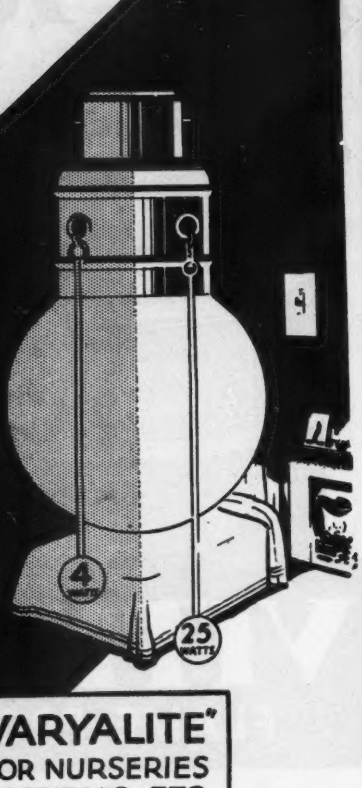
When you use SIMPLEX or CREDALUX you are assured of the most up-to-date and efficient Electric Lighting Equipment for all industrial, commercial and municipal purposes that modern practice can devise—at competitive prices. WRITE FOR LISTS.

SIMPLEX ELECTRIC CO. LTD.
Empire House, 159 Gt. Charles St., Birmingham
Branches at:
LONDON, BIRMINGHAM, BRISTOL, CARDIFF, GLASGOW LEEDS, LEICESTER, LIVERPOOL, MANCHESTER, NEWCASTLE, NOTTINGHAM, SHEFFIELD

SIEMENS

OPAL LAMPS

TUBULAR LAMPS
FOR MODERN DECORATIVE LIGHTING



"VARYALITE"
FOR NURSERIES HOSPITALS, ETC.

STANDARD "SILVALUX" OPAL
FOR GENERAL LIGHTING

THERE IS A SIEMENS LAMP
for every lighting requirement

MADE IN ENGLAND

Makers of **SIEMENS ELECTRIC LAMPS AND SUPPLIES LIMITED.** 38/39, Upper Thames Street, London, E.C.4.
Branches at-Belfast, Birmingham, Bristol, Cardiff, Dublin, Glasgow, Leeds, Liverpool, Manchester, Newcastle-on-Tyne, Nottingham, Sheffield, Southampton.

THE ILLUMINATING ENGINEER
THE JOURNAL OF
GOOD LIGHTING
LIGHT
LAMPS
FITTINGS
AND
ILLUMINATION
OIL
GAS
ELECTRICITY
ACETYLENE
PETROL-AIR
GAS
ETC.
OFFICIAL JOURNAL of
The Illuminating Engineering Society
(Founded in London, 1909. Incorporated 1930)
and of
THE ASSOCIATION OF PUBLIC LIGHTING ENGINEERS
(Founded 1923; Incorporated 1928)

Vol. XXVI March, 1933 Price NINEPENCE
Subscription 10/6 per annum, post free.

Edited by
J. STEWART DOW

EDITORIAL AND PUBLISHING OFFICES:
32 VICTORIA STREET, LONDON, S.W.1.
Tel. No.: Victoria 5215

Everyday Photometry with Photo-Electric Cells

THE application of the photo-electric cell to photometry, which Dr. Walsh discussed so lucidly at the last meeting of the Illuminating Engineering Society, on February 14th, is undoubtedly one of the most striking developments within recent years. There are, as Dr. Walsh explains, three main types of such cells, having different characteristics and limitations. Once these are understood their utility is considerable, and in the photometric laboratory their use has already become familiar. They furnish a most valuable weapon in research—for example, in studying relatively minute changes and in confirming such results in cases where an observer, by ordinary photometric methods, is liable to be misled by personal impressions, or where the personal element is otherwise apt to play a part. To have a corroborative process, independent of the procedure of establishing, through the agency of the eye, equality of brightness in a photometer, is a useful thing—even though, as one must recognize, such physical methods of measurement have ultimately to be calibrated by reference to the established method of visual photometry. The photo-electric cell may also serve to relieve workers of a great deal of tedious and rather fatiguing routine observations, and renders possible the aid of workers without any special photometric skill in photometry. In laboratories dealing with the regular testing of electric incandescent lamps on a large scale such methods have proved of established value.

Equally important is the application of the photo-electric cell to recording processes, such as the continuous measurement of daylight. A striking advance of this type mentioned by Dr. Walsh, which seems destined to effect considerable time-saving in the laboratory, is the apparatus developed abroad for the automatic registration of polar curves of light-distribution. In almost all fields of work continuous registration of phenomena plays an important part. In photometry, until recently, all that was possible was the taking of results at frequent intervals, and in some cases—the rapid change in illumination at the crucial point in a solar eclipse furnishes a good example—an observer using ordinary photometric methods finds it extremely difficult to keep pace with the effect. In future it should be possible to study and record transient and variable light-effects by the aid of the photometric cell, which should prove of utility in the examination of sources of light for constancy.

The most fascinating application of photo-electric methods, however, is to the portable illumination photometer. Present types of illumination photometers, though far handier, easy to use and accurate than those available a few years ago, do still present difficulties to the layman (by "layman" in this connection we mean anyone without training in a photometric laboratory).

There are two main difficulties. Firstly, the process of using the photometer—obtaining equality of brightness in the photometric field—presents obstacles to many people whose eyes are not particularly sensitive to change in brightness or trained to observe them. Secondly, the fact of having to maintain an accumulator in good order is often a trouble, even if in these days of wireless it has become a familiar one. Forms of photo-electric cells which demand the use of a source of current and a highly sensitive galvanometer offer only a partial solution. But the photo-voltaic cell has the great advantage of offering a means of eliminating both difficulties. Already there are available instruments utilizing these cells which apparently fulfil the long-awaited condition that one obtains a reading of the pointer on a dial merely by exposing the cell to the illumination to be measured. There are admittedly some limitations—it seems as yet difficult to measure relatively low illumination in this way, and there are certain features of the reactions of the cells to light which seem to require further study.

The most formidable query at present seems to be the uncertainty as to how such cells react to the spectra of various illuminants. We believe, however, that the problem of ensuring conditions of response closely resembling those of the normal eye for all ordinary types of incandescent illuminants (such as the electric tungsten-filament lamp and the incandescent gas mantle) should not prove too difficult. In the case of the varied spectra characteristic of the luminous discharge lamps now coming into use the difficulty of ensuring that the cell behaves in the same manner as the normal eye is certainly greater. But the general use of luminescent gases would admittedly render even standard visual photometric methods difficult to apply. The comparison of sources of light of this description has long been recognized as difficult, so that the question of the response of photo-electric cells is only part of a much wider problem—how far any results obtained by instrumental means can be related to the effect on the eye of large surfaces illuminated by highly coloured light.

Illuminating Engineering Society

(Founded in London, 1909; Incorporated 1930).

Election of Officers and Council Session 1933-1934

OFFICIAL NOTICE

IN accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon. Secretary, and Ordinary Members of Council, is presented herewith for the information of the Members of the Society.

In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 48):—

> "After the issue of the Council's list, and not later than the *15th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nominations in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

Present Officers and Members of Council

President*:—*Lt.-Commander Haydn T. Harrison, M.I.E.E., R.N.V.R.

***Past Presidents*:—**

Sir WILLIAM BENNETT, K.C.V.O., F.R.C.S.
Mr. A. P. TROTTER
Sir JOHN HERBERT PARSONS, C.B.E., F.R.S.
Mr. D. R. WILSON, C.B.E.
Mr. C. C. PATERSON, O.B.E., M.I.E.E.
Dr. J. W. T. WALSH, M.A., D.SC., M.I.E.E.
Lt.-Col. K. EDGCUMBE, T.D., M.INST.C.E., M.I.E.E.
Sir FRANCIS GOODENOUGH, C.B.E.

***Vice-Presidents*:—**

Mr. C. W. SULLY (1930)
Mr. H. HEPWORTH THOMPSON (1931)
Mr. A. W. BEUTTELL (1932)

***Members of Council*:—**

Mr. L. E. Buckell (1930)
Mr. H. Buckley (1930)
Mr. A. CUNNINGTON (1932)
Mr. R. S. DOWNE (1932)
Mr. J. ECK (1931)
Dr. S. English (1930)
Col. C. H. SILVESTER EVANS (1932)
Mr. C. HUGHES (1932)
Mr. W. J. JONES (1932)
Mr. S. B. LANGLANDS (1931)
Capt. W. J. LIBERTY (1931)
Mr. C. A. MASTERMAN (1932)
Mr. W. MILLNER (1931)
Mr. F. W. Purse (1930)
Mr. HOWARD ROBERTSON (1931)
Mr. John Terrace (1930)
Mr. J. C. WALKER (1931)
Mr. H. C. WHEAT (1931)
Mr. H. T. Young (1929)

Hon Secretary*:—*Mr. J. Stewart Dow (1928)

Hon. Treasurer*:—*Mr. J. Wyatt Ife (1909)

Nominated by the Council to fill Vacancies

***President*:—**

Mr. C. W. SULLY

***Vice-Presidents*:—**

Mr. A. CUNNINGTON

***Members of Council*:—**

Mr. A. C. CRAMB
Miss C. HASLETT
Mr. A. E. ILIFFE
Mr. STEPHEN LACEY
Mr. T. E. RITCHIE
Mr. ERNEST STROUD
Mr. G. H. WILSON

***Hon. Secretary*:—**Mr. J. STEWART DOW.

***Hon. Treasurer*:—**Mr. PERCY GOOD.

The names in italics are those of retiring Officers or Members. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

TECHNICAL SECTION

COMPRISING

Transactions of The Illuminating Engineering Society and Special Articles

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

Everyday Photometry with Photo-Electric Cells

(Proceedings at the Meeting of the Illuminating Engineering Society, held in the Lecture Theatre of the Institution of Mechanical Engineers, at 6-30 p.m., on Tuesday, February 14th, 1933.)

A MEETING of the Illuminating Engineering Society took place in the Lecture Hall of the Institution of Mechanical Engineers, on Tuesday, February 14th. Members assembled for light refreshments at 6-30 p.m., and the chair was taken by the President (Lt.-Commander Haydn T. Harrison) at 7 p.m.

The minutes of the last meeting having been taken as read, the HON. SECRETARY read out the names of applicants for membership, which were as follows: —

Sustaining Members :—

The Gas Light and Coke Company, Horseferry Road, Westminster, S.W.1.

Corporate Members :—

Agar, W. H. .....Electrical Engineer, W. H. Agar Ltd., 11A, Union Court, Old Broad Street, London, E.C.

Brooker, W. G. .....Illuminating Engineer, 14, Boreham Road, Wood Green, London, N.22

Van Ryn, J. H. .....Electrical Contractor, The Lodge, Beaconsfield Road, Willesden, London, N.W.10.

Mention was also made of a transfer from Associate Membership to Corporate Membership on the part of Mr. A. G. Winsor, of Merrowdown, 20, Kingsway, Woking.

The names of those announced at the last meeting of the Society were read again, and these gentlemen were formally declared members of the Society.*

The PRESIDENT then called upon Dr. J. W. T. WALSH to present his paper entitled "Everyday Photometry with Photo-electric Cells." The paper, which was illustrated by numerous lantern slides, explained the characteristics of the three chief classes of photo-electric cells, namely, the Elster-Geitel, selenium and photo-voltaic varieties, and illustrated the nature of the response of these various cells to light and their sensitivity throughout the spectrum. Subsequent sections dealt with the measurement of candle-power, luminous flux and illumination, the determination of polar curves, and the preparation of records of illumination. A new form of illumination-photometer utilizing the Weston "Photronic" cell was shown by the lecturer, and Lt.-Col. K. Edgcumbe exhibited a form of integrating cube utilizing a photo-electric cell.

An interesting discussion ensued, in which the following, amongst others, took part: Lt.-Col. KENELM EDGCUMBE, Mr. G. T. WINCH, Mr. L. T. MINCHIN, Mr. H. PRESTON, Mr. H. BUCKLEY, Mr. A. G. AVENT, Mr. E. STROUD, Mr. A. SOAMES, and the PRESIDENT.

After Dr. Walsh had briefly replied to various points raised in the discussion, a vote of thanks to him for his address was moved by the President, and passed with acclamation.

The HON. SECRETARY, in announcing the next meeting of the Society, of which particulars appear below, mentioned that the present was the first occasion on which members had met in the lecture theatre of the Institution of Mechanical Engineers. The privilege of doing so had been specially granted by the Council of the Institution, and was, he felt sure, much appreciated by members of the Illuminating Engineering Society.

* *Illum. Eng.*, February, 1933, p. 31.

The Illuminating Engineering Society

FORTHCOMING MEETINGS.

Members are reminded that the **Next General Meeting** will be held in the Lecture Theatre of the Institution of Mechanical Engineers (Storey's Gate, St. James's Park, London), by kind permission of the Council of the Institution, at **6-30 p.m.,** on **March 15th,** when an address reviewing **"Developments in Illuminating Engineering Abroad"** will be delivered by **Dr. Halbertsma,** of Holland.

The subsequent General Meeting will likewise be held in the Lecture Theatre of the Institution of Mechanical Engineers on April 11th, when a paper on "The Lighting of Hospitals" will be read by Mr. F. C. Raphael.

Lectures on Illumination

Lectures on illumination, arranged by the Polytechnic with the co-operation of the National Illumination Committee and the Illuminating Engineering Society, commenced on February 8th, when the opening address on "Light in the Service of Mankind" was delivered by Mr. C. C. Paterson. Lieut.-Col. Kenelm Edgcumbe (Chairman of the National Illumination Committee), in opening the proceedings, mentioned that four of the lectures had been specially arranged at the E.L.M.A. Lighting Service Bureau, Watson House, the East London College, and the Home Office Industrial Museum, which had been freely placed at the service of the organizers of the lectures, and that those participating in the course would have the privilege of visiting the National Physical Laboratory and the G.E.C. Research Laboratories at Wembley. Finally, he expressed the hope that it would be found possible to publish the lectures after their delivery.

Everyday Photometry with Photo-Electric Cells

By J. W. T. WALSH, M.A., D.Sc., M.I.E.E.

(Paper read at the Meeting of the Illuminating Engineering Society, held at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m., on Tuesday, February 14th, 1933.)

ABSTRACT

This paper gives first a brief outline of the principal characteristics of photo-electric cells, as far as they affect the use of such cells for photometric measurements. The most generally used apparatus for the various classes of photometric measurement are then described. These are (1) a photometer for the measurement of directional candle-power, (2) an integrating photometer for measurement of luminous flux, (3) an illumination photometer using the Elster-Geitel cell, (4) an illumination photometer using the photo-voltaic cell. At the end of the paper brief reference is made to other applications of photo-electric cells for different types of photometric measurement.

Introduction.

It will probably be agreed that the most striking development which has occurred in photometric practice during the present century is the introduction of methods of measurement depending upon the use of the photo-electric cell in place of the eye. In what follows it will be assumed that everyone is familiar with the different types of cell now commonly employed. These are conveniently divided into three classes, viz.: (i) the Elster-Geitel cell, now available in many different forms, (ii) the selenium cell (and others of the same type), and (iii) the photo-voltaic, or rectifier, form, known in Germany as the " Sperrschicht " cell.

The Elster-Geitel form consists essentially of an air-tight glass bulb containing a light-sensitive kathode (usually a film of one of the alkali metals) and a metal ring, gauze or plate which serves as the anode. Fig. 1, which is purely diagrammatic,

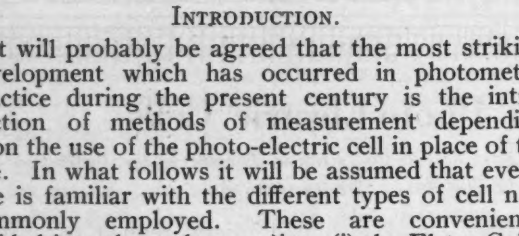


Fig. 1.—The Elster-Geitel Photo-Electric Cell.

illustrates this form of cell. The bulb may be either evacuated or gasfilled. The sensitive kathode surface may consist of a thick layer of the alkali metal, or it may be a very thin (so-called monomolecular) film, deposited on an oxidized copper or silver layer. The voltage is applied between the kathode and the anode, and the current flowing through the cell depends on the illumination of the sensitive surface of the kathode. This current is very minute, and may be of the order of one to ten microamperes per lumen of flux reaching the surface.

The selenium cell consists essentially of a strip of selenium between two electrodes, as shown diagrammatically in Fig. 2. The current flowing from

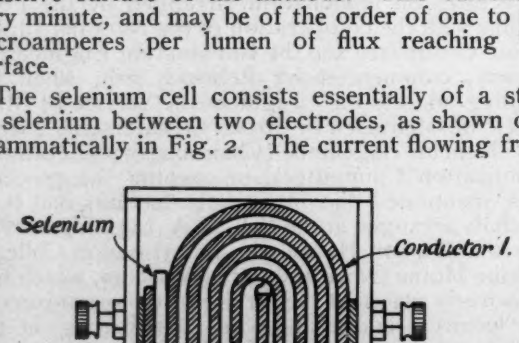


Fig. 2.—The Selenium Cell.

one electrode to the other through the selenium depends on the illumination of the latter, and by designing the cell so that the distance betwen the electrodes is very small, while the length of the selenium strip separating them is as great as possible, the current flowing through the selenium from one electrode to the other may be raised to something of the order of a miliampere for 10 foot-candles illumination, measured at the surface of the selenium.

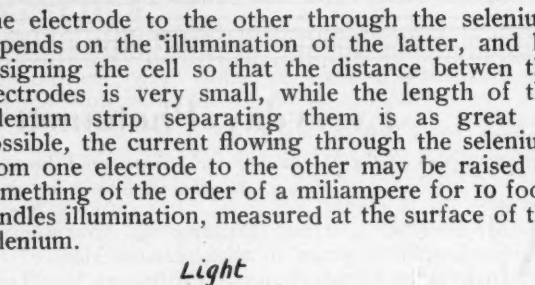


Fig. 3.—The Rectifier, or Photo-Voltaic Cell.

The photo-voltaic (rectifier) cell consists of a metal plate coated with a thin layer of some semi-conductor, the upper surface of which is covered with a very thin film of metal. The two metal layers (i.e., the plate and the film) form the electrodes and are directly connected to the terminals of a current-measuring instrument, as no battery is needed with this form of cell (see Fig. 3). When light falls on the metal film some of it penetrates to the semi-conductor and a current flows in the circuit, the direction of this current being from the plate to the film through the measuring instrument. The strength of the current varies with the illumination of the cell.

In the first cells of this type the plate and the metal film were of copper, the semi-conducting layer being cuprous oxide. In fact, the cell was precisely similar to an element of a copper-copper oxide rectifier. For this reason, this type of cell is at present widely known as the " rectifier " type. Other metals and semi-conductors are now being employed with the object of improving the performance of the cell, particularly as regards its spectral sensitivity curve. The Weston " Photronic " cell is stated to consist of an iron plate coated with selenium, the metal film being of copper treated by a special process.

It is clearly impossible even to mention the many different modifications which have been made in each of these various types of cells. To do so would require many pages, and those who wish to know more are referred to one or other of the books which have recently been published on the subject.*

* " Photo-electric Cells," by N. R. Campbell and D. Ritchie. (Pitman, 1929.)
" Photocells," by V. K. Zworykin and E. D Wilson. (Wiley, 1930.)
" The Selenium Cell : Its Properties and Applications," by G. P. Barnard. (Constable, 1930.)
" Lichtelektrische Zellen und ihre Anwendung," by H. Simon and R. Suhrmann. (Springer, 1932.)
" Die Lichtelektrische Zelle und ihre Herstellung," by Fleischer and Teichman (Steinkopf, 1932.)

For similar reasons no attempt will be made to describe, or even to mention, the many directions in which these cells have been applied to purposes other than the *measurement* of light. This paper will be strictly confined to a description (and that in outline) of typical methods of photo-electric photometry. Historical matter must be left out, and even the theory underlying the action of a photo-electric cell must be taken for granted. The books already referred to above may be consulted for information on these matters.

The reason for this paper is the fact that everyone who is brought into contact with photometric measurement has been, or will certainly soon be, forced to ask himself whether he ought to adopt some photo-electric method. To give an answer to this question it is necessary to know the type of measurement under consideration, the conditions under which it has to be made and the degree of precision required. This, with a knowledge of what modern photo-electric methods can achieve, their limitations and the conditions necessary for successful working, will enable a reply to the question to be framed on definite knowledge rather than on vague surmise or, worse still, blind imitation.

The Response of the Photo-electric Cell to Light.

The ideal photo-electric cell would provide a current which was strictly proportional to the illumination at the cell for all values of this illumination, no matter what the colour of the light, its angle of incidence or state of polarization. Further, the strength of this current should always be the same for the same illumination, and it should preferably be sufficient to deflect a robust and accurate measuring instrument when the illumination has a value of the order of one foot-candle. Needless to say, not one of these requirements is even nearly satisfied in any of the cells available for practical work.

In the first place let us take the requirement of proportionality between current and illumination, when colour, angle of incidence and state of polarization are kept constant. Fig. 4 shows

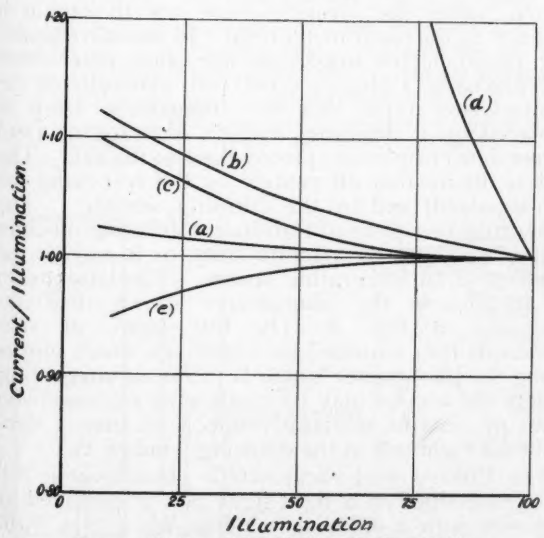


Fig. 4.—Change of Sensitivity with Illumination.

(*a*) Elster-Geitel Vacuum Cell.
(*b*) Elster-Geitel Gasfilled Cell.
(*c*) Thin-film Potassium Cell.
(*d*) Selenium Cell.
(*e*) Photo-Voltaic (Weston) Cell.

typical sensitivity-current curves for (*a*) an Elster-Geitel cell (vacuum type), (*b*) an Elster-Geitel cell (gasfilled type), (*c*) a thin-film potassium cell, (*d*) a selenium cell, (*e*) a photo-voltaic cell. It will be seen that in the case of the gasfilled Elster-Geitel cell and the selenium cell proportionality between current and illumination can only be assumed over a very limited range. With the other types, however, it is possible, by careful design, to obtain a much closer approximation to the desired linear relationship and cells of the Elster-Geitel (vacuum type), whether the kathode surface be bulk alkali metal or a thin-film on oxidized metal, can be constructed so as to give a current proportional to the illumination, within 1 or 2 per cent., over a very wide range. The same appears to be true of certain kinds of photo-voltaic cells.

Colour sensitivity is a matter of great importance, and the limitations of the photo-electric cell in this respect cannot be too clearly realized. As might be expected, no cell responds to the various wavelengths in the visible spectrum in precisely the same way as does the human eye. Some typical spectral sensitivity curves are shown in Fig. 5, and the corresponding curve for the eye is also shown.

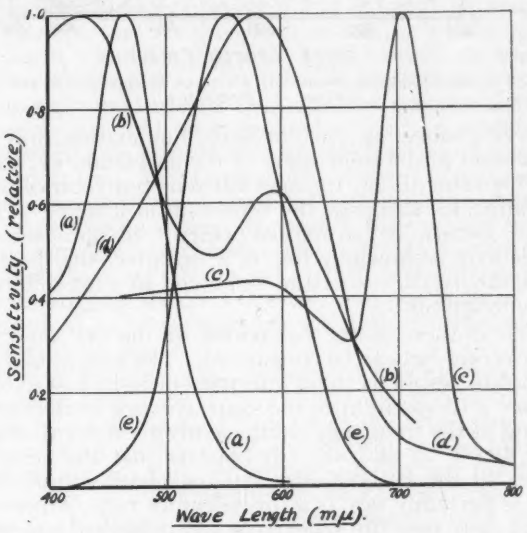


Fig. 5.—Spectral Sensitivity Curves.

(*a*) Elster-Geitel Vacuum Cell.
(*b*) Thin-film Potassium Cell.
(*c*) Selenium Cell.
(*d*) Photo-Voltaic Cell.
(*e*) Human Eye.

The obvious cure for this defect is a colour filter having a transmission curve such that the spectral sensitivity of the combination of cell and filter is a close imitation of that of the eye. Unfortunately for this method of correction, not only is there a serious loss of sensitivity due to the absorption of light by the filter, and, usually, a change of transmission of the filter with change of temperature, but, what is far worse, no two cells, even of the same type and design, have precisely the same spectral sensitivity curve. It follows that photo-electric methods can only be employed in high-precision work so long as the lights to be compared have almost exactly the same spectral composition. For less precise work a sufficiently good combination of cell and filter can usually be found.

There is one possible source of error which must be mentioned here, and it is not always obvious. Suppose a cell, not fully corrected for colour sensitivity, is to be used to compare a light L_1 with another light L_2 of exactly the same colour but of different intensity. One method of making such a measurement is to have a third light M which can be varied in a known manner, and to find the values of this light, M_1 and M_2 say, at which it gives the same effect on the cell as L_1 and L_2 respectively. It is then natural to deduce that $L_1/L_2 = M_1/M_2$, but *unless M has exactly the same spectral composition as L_1 and L_2*, this is not necessarily the case, for the

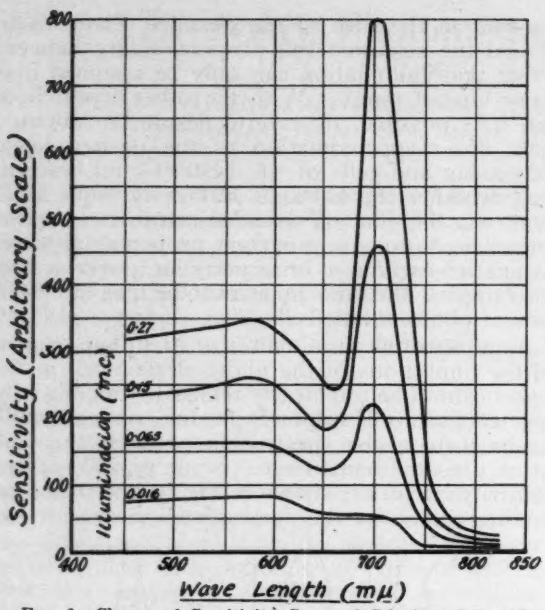


FIG. 6.—Change of Sensitivity Curve of Selenium Cell with Change of Illumination.

curve connecting current with illumination may be different at different parts of the spectrum, or, what is the same thing, the spectral sensitivity curve may change its shape as the illumination alters.* That this occurs to a marked extent in the case of selenium is shown by Fig. 6, which gives the spectral sensitivity curves of the same cell at four different illuminations.

Next there is the behaviour of the cell under a flickering light to be considered. The eye, as is well-known, responds to an intermittent light just as if it were a steady light of the same average intensity (so long as the frequency is sufficiently great for all sense of flicker to be lost). It appears that the same is true of the Elster-Geitel type of photo-voltaic cell. It is certainly not true of selenium cells, however, and there does not seem to be any published information available on this matter in the case of photo-voltaic cells.†

The effects of angle of incidence of the light and of its state of polarization are only important in certain types of photometric measurement, and their consideration can therefore be postponed for the present.

Finally, there is the important matter of stability and absence of secular change of sensitivity. It appears that most well-constructed photo-electric cells of the Elster-Geitel type may be relied upon to maintain constant sensitivity over long periods, especially if they are not exposed to high illuminations but are kept in the dark for most of the time. There is as yet, however, insufficient information on this matter with regard to the photo-voltaic cells. What is, perhaps, more important is the fact that in all types of photo-electric cells the sensitivity is affected by change of temperature, though this effect is more marked in some types than in others. For an Elster-Geitel cell the change may be of the order of 1 per cent. for a change of 5° Centigrade; for the Weston type of rectifier cell it is about half as much as this.‡ It must be remembered, too, that a change of temperature may also affect auxiliary apparatus in a photo-electric photometer, e.g., colour-filters used to correct the sensitivity curve of the cell, or the very high resistances needed in certain parts of the apparatus.

Previous or continued exposure to light may produce a change in the sensitivity of a photo-electric cell. This effect is often called "fatigue," and some typical curves showing what may happen with cells of the Elster-Geitel type are shown in Fig. 7.

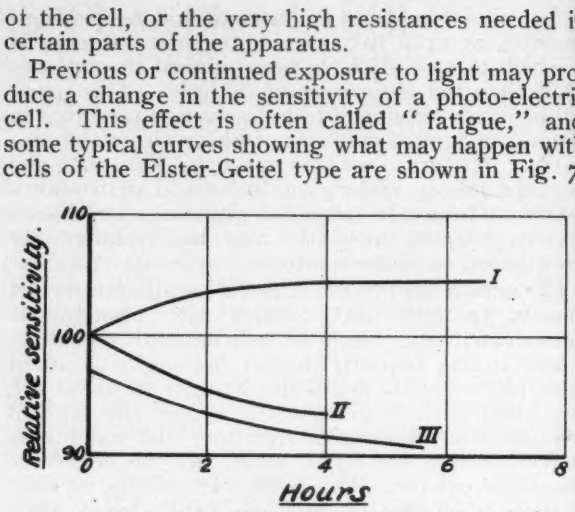


FIG. 7.—Change in Sensitivity with Time of Exposure to Light.

It might be thought that, after such a catalogue of the ways in which the response of a photo-electric cell to a given illumination may be affected by quite other factors than the actual value of that illumination, any attempt to use these cells for photometric measurement would be foredoomed to failure. It is a tribute to the patience and ingenuity of those who have laboured in this field that to-day photometry by means of photo-electric cells is rapidly becoming an established technique, and the object of the following sections of this paper is to describe that technique quite briefly and without any attempt to indicate the reasons that have led to the adoption of some particular arrangement of apparatus. Closer examination will generally show that the arrangement actually used has been dictated by the necessity for avoiding one or other of the sources of error briefly mentioned in the preceding paragraphs.

THE MEASUREMENT OF CANDLE-POWER.

Visual measurements of luminous intensity in a given direction are generally made on a photometer bench, using the inverse-square law to obtain a balance in the photometer head. In the corresponding photo-electric apparatus the photometer head is replaced by a photo-electric cell, generally of the Elster-Geitel type, and the comparison lamp is replaced by a diffusing surface of constant (and convenient) brightness placed close to the cell. The cell is illuminated alternately by the test lamp (or sub-standard) and by the diffusing surface. The latter may be a piece of translucent diffusing medium illuminated by a comparison lamp, or it may be the window of an integrating sphere. The latter form is adopted in the photometer shown diagrammatically in Fig. 8. The test lamp, or sub-standard, L is mounted on a carriage which moves along the photometer bench B. S is an integrating sphere (or a cube may be used) with a comparison lamp of suitable wattage inside it to give a convenient brightness at the diffusing window W_2.

The Elster-Geitel vacuum type photo-electric cell C_1 is contained in a light-tight box Z provided at one side with a diffusing window W_1. The light transmitted by W_1 falls on the cell and controls the current passing through it. The box Z and its contents can be easily and quickly rotated through 90° in the clockwise direction about an axis perpendicular to the plane of the figure. By this rotation W_1 is brought round to face W_2 instead of L. Two colour filters, placed as shown, correct the sensitivity curve of the cell so as to bring it into approximate agreement with that of the eye.

* It is well-known that the spectral sensitivity curve of the eye (the so-called "visibility" curve) is quite different at low illuminations from that shown in Fig. 5.

† Tests made at the N.P.L. on one particular form of photo-voltaic cell showed that it obeyed Talbot's law, i.e., it behaved to a flickering light in the same manner as the eye.

‡ A. H. Lamb, *El. World*, Vol. 99, p. 693, April, 1932.

The basis of the method is that by moving L on the bench, the current passing through the cell C_1 may be made the same for both positions of the box Z. If this is done for two different lamps, L_1 and L_2, placed successively on the bench carriage it follows that $L_1/\overline{L_1W_1}^2 = L_2/\overline{L_2W_1}^2$, for clearly the brightness and position of W_2 remains the same throughout.

A direct adjustment of the kind just described would be very tedious to carry out, for each shift of L would have to be followed by a rotation of Z. A simpler scheme is to balance the current through C_1 when W_1 faces W_2, and then to rotate Z back to the position shown and shift L until the balance is restored. This procedure is made possible by using a balancing lamp L′ which illuminates a second photo-electric cell C_2. C_1 and C_2 are connected to an electrometer* and a battery in such a way that, when the currents passing through the cells are equal, the electrometer receives no charge.

The procedure in making a measurement, then, is (i) to turn Z so that W_1 faces W_2 and adjust the voltage on L′ until there is no deflection of the electrometer needle when the earthing key is raised. (ii) to turn to Z so that W_1 faces L_1 (the test lamp, say) and to move L_1 until there is again no deflection on the electrometer when the earthing key is raised. This gives L_1W_1. An exactly similar procedure is then followed with L_2 (the sub-standard) substituted for L_1 (the lamp in S being, of course, unchanged), and thus L_2W_1 is found.

As in the case of visual photometry, it is usual to employ more than one sub-standard for a set of measurements, and, naturally, any convenient number of test-lamps may be measured by comparison with a single set of sub-standards. It is common practice to divide the sub-standards to be used into two groups, and to " sandwich " the test lamps between these two groups.

The cells C_1 and C_2 may conveniently be of the rubidium or potassium thin-film variety, and the correcting filters may then consist of glass cells filled with a mixture of three dilute solutions containing respectively cupric chloride, cobalt-ammonium sulphate and potassium dichromate. The proportions to be used necessarily depend on the spectral sensitivity curve of the cell C_1. A method of determining these proportions in any given case is to be described in a forthcoming paper by J. S. Preston and L. H. McDermott.

* A Compton electrometer is actually employed in the photometer here described.

The reason for the insertion of the diffusing window at W_1 is that the position of the sensitive surface in the photo-electric cell cannot be determined with any precision. The basis of the method is, however, the variation of illumination according to the inverse-square law, and it is therefore necessary to provide a well-defined surface, the distance of which from L can be measured precisely. Clearly the illumination of W_1, and therefore the amount of light falling on C_1, will vary inversely as the square of LW_1 where the points of measurement are respectively the axis of L (or its filament plane in the case of a uniplanar filament lamp) and the diffusing surface in W_1 which is nearest to L. W_1 may conveniently consist of two thin plates of clear glass ground on each side so that there are three diffusing surfaces in series.

A different method of applying the inverse square law has been used by P. Fleury.* An opaque screen with an aperture of suitable size is placed between L and the photo-electric cell (see Fig. 9), and a lens Q is inserted in such a position that it forms an image of this aperture on the sensitive surface of the cell. A much reduced image of L is formed at some intermediate position. With this arrangement it is clear that the area of the sensitive surface illuminated is constant, and the amount of flux reaching it is strictly proportional to the flux passing through the aperture. This latter must clearly vary inversely as the square of the distance of L from the aperture, a quantity which may be readily determined to a high degree of precision. The only possible defect is that the area of the lens which transmits light varies slightly as L is moved, and the method is dependent on absolute constancy of the transmission factor of the lens.

It will be clear that, instead of having an integrator to illuminate W_2 any constant lamp in a light-tight box may be used so long as the brightness of the external surface of W_2 can be adjusted to a convenient value. Further, instead of rotating the cell in its box, a movable mirror may be arranged so that C_1 is illuminated alternately by W_1 and W_2. Needless to say, other modifications of detail may be made without affecting the general principles on which the design of the apparatus is based.

The Measurement of Luminous Flux.

The apparatus shown in Fig. 8 may also be used for measuring the luminous flux of any lamp which can be conveniently inserted in the sphere S. All

* *Revue d'Optique*, Vol. 11, p. 385, October, 1932.

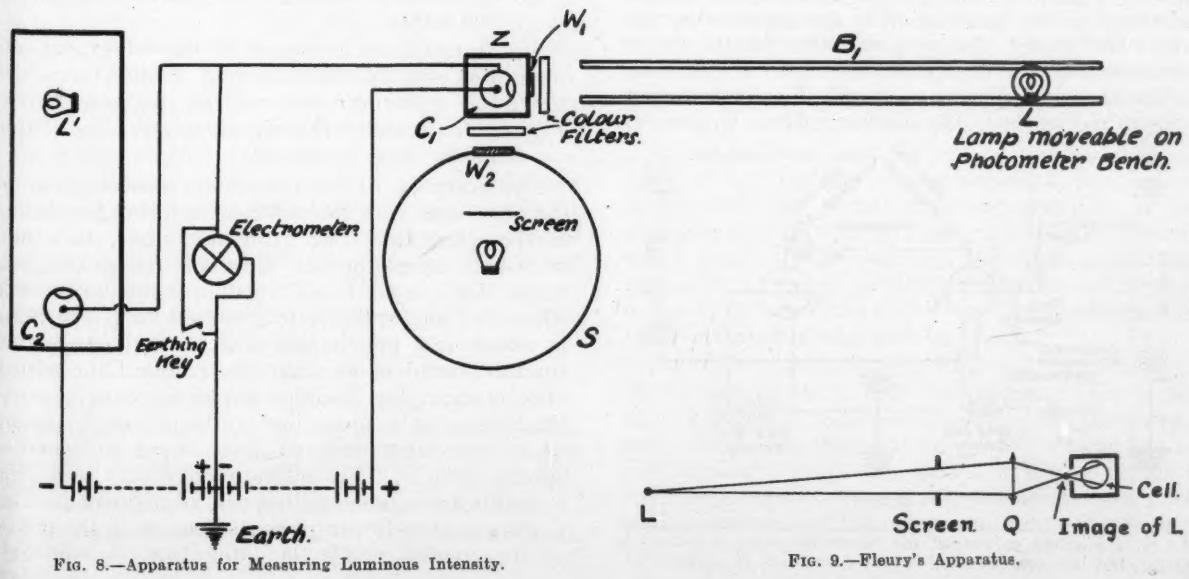


Fig. 8.—Apparatus for Measuring Luminous Intensity.

Fig. 9.—Fleury's Apparatus.

that is needed is a comparison lamp of suitable candle-power at L and a set of sub-standards of luminous flux for insertion in S before and after the test lamps. It will be seen, however, that the illumination of the cell C_1 is not the same throughout the measurements, but is different for each lamp. For this reason the light from L should be of the same spectral distribution (at least approximately) as that from the window W_2 when the sub-standards or test lamps are in the sphere.

For routine measurements of lamps, such as those made during a life-test, or for the initial rating of electric lamps in a factory, a much more rapid method than that just described can be employed. Several such methods have been described at various times, but for the purpose of this paper it will be sufficient to refer to one which has now been in use in this country for some time, and has proved itself trustworthy so long as reasonable precautions are taken to maintain it in good order.

The photometric part of the apparatus consists, necessarily, of a photometric integrator, either a sphere or a cube. The window, or aperture, at one side of this integrator gives on to another integrator or some form of light-tight box containing a suitable type of photo-electric cell (e.g., a thin-film potassium cell). This part of the apparatus is shown diagrammatically in Fig. 10. The window is covered with

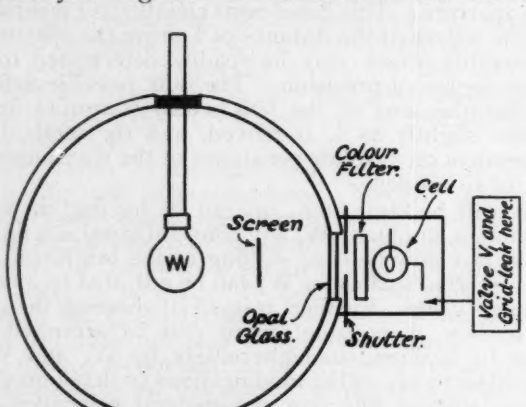


FIG. 10.—Apparatus for Measuring Luminous Flux.

a colour filter to correct the sensitivity curve of the particular cell used. It may also be provided with some form of shutter which enables the effective area of the window to be altered at will. The basis of the method is the assumption that the current passing through the photo-electric cell is proportional to the illumination of the sensitive surface over the range covered by the lamps to be measured.*

The electrical circuits used with this apparatus are shown in Fig. 11. The similar valves, V_1 and V_2,

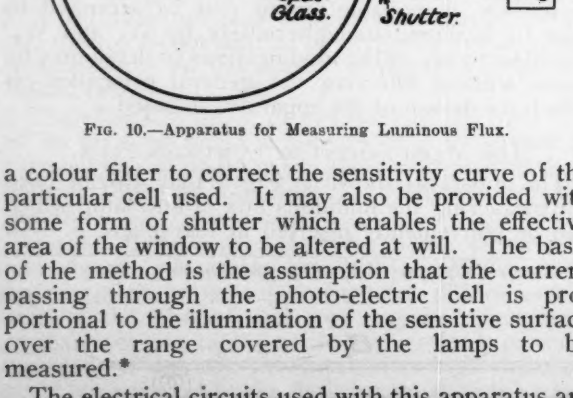


FIG. 11.—Apparatus for Measuring Luminous Flux.

* It is possible to extend the range by using a correction factor, but this complication is better avoided, if possible.

are arranged in bridge form, as shown in the right-hand half of the diagram. The bridge is balanced with the potentiometer P at zero and the photo-electric cell in the dark. When the cell is illuminated the current flowing through it alters the grid potential and upsets the balance of the bridge, as shown by a deflection of the galvanometer. The balance can be restored by readjusting the grid bias with the potentiometer, and the extra grid-bias voltage needed for this purpose is a measure of the photo-electric current. With this apparatus it is possible to have a linear relation between grid-bias voltage and luminous flux over a considerable range (e.g., 10 to 1.)

A difficulty sometimes encountered with this apparatus is a gradual drift of zero due to the valves, lasting, perhaps, for as long as several hours. The trouble, when it arises, may be overcome by keeping both the high- and low-tension batteries permanently connected, except when they have to be removed for charging.

It is convenient to be able to adjust the apparatus so that the potentiometer reads directly in lumens. This may be achieved (*a*) by altering the value of the grid leak in the photo-electric cell circuit, and (*b*) by altering either the area of the window between the integrator and the box containing the photo-electric cell, or else the current through the potentiometer P. In practice (*a*) is used as a coarse and (*b*) as a fine adjustment.

The procedure employed in making a set of measurements is as follows:—

(i) The potentiometer is set to zero, and the galvanometer is balanced by adjusting the grid bias on V_2, the cell being in the dark.

(ii) A sub-standard giving a luminous flux of, say, F lumens is placed in the integrator and the potentiometer is set to a scale-reading F. The galvanometer is brought to zero by moving the sliding shutter over the integrator window (and altering the grid-leak, if necessary). This is done for several different sub-standards giving respectively F_1, F_2, F_3 . . . lumens, and the shutter position is adjusted to the mean of the various slightly different positions found for it.

Alternatively, the integrator window is left unaltered, and the balance is obtained in each case by adjusting the current passing through the potentiometer. The mean value of the currents found for the various sub-standards is then used during the measurements on the test lamps.

(iii) A test lamp is placed in the integrator and the potentiometer setting found for which the galvanometer returns to zero. The potentiometer reading then gives the output of the lamp in lumens.

The accuracy of the colour correction given by the filter used with the cell can be tested by placing in the integrator, one after the other, two sub-standards operating at different colour-temperatures, e.g., 2360° K (a vacuum lamp at normal efficiency) and 2700° K (a gasfilled lamp operating at about 12.5 lumens per watt). Sometimes it is found convenient to make the colour filter adjustable by arranging it so that it does not entirely cover the integrator window, but can be moved, by means of a fine adjustment, so as to leave a larger or smaller area of the window uncovered. It is clear that this arrangement allows of adjustment to compensate for slight progressive changes in the colour of the coating inside the integrator, as well as a

small specular change in the colour sensitivity of the cell.

One of the most important precautions necessary with this apparatus is the thorough screening of the electrical circuits (particularly the parts including the photo-electric cell, the valve V_1 and the grid-leak) from any possible electrical disturbance. Movement of the various elements relative to each other must be carefully guarded against, and G. T. Winch, who has had a great deal of experience in the application of this type of apparatus to factory working, has written as follows:—*

> "It is found that the valves themselves are sensitive to heavy vibration of the apparatus even when mounted in holders on Sorbo rubber, and it is desirable to "nest' them in cotton-wool in order to overcome this trouble. It might be wise, in a design required for use under factory conditions, to mount the whole of the cell and amplifier equipment on a mounting separate from the photometric integrator equipment in order to insulate the valves from shock."

The careful selection of the valves is another most important matter, and "matched" pairs of valves of similar characteristics are necessary for accurate work.

When all the precautions mentioned above have been taken, it should be possible to measure lamps operating anywhere within the range 4 to 15 lumens per watt, and over a lumen range of at least 5 to 1 with an error of not more than about 1 to 1.5 per cent.† The speed of working is certainly much higher than that attainable in visual photometry to a similar order of accuracy, especially if the almost complete absence of calculation and the simplicity of booking be taken into account. There is, moreover, the great advantage that the work may be performed in a room well provided with daylight, instead of the dark and dismal apartment usually associated with photometric work.

The Measurement of Illumination.

It will be clear that, by making certain modifications of a more or less obvious kind, either of the methods described in the last two sections of this paper might be used for the measurement of illumination. Several portable instruments have, in fact, been devised along these lines. Among these may be mentioned first the photometer exhibited at the 1932 Exhibition of the Physical and Optical Societies by the Research Laboratories of the General Electric Company.‡ In this instrument, which is still in the experimental stage, the system used is similar to that described in the last section. The photo-electric cell, valves and grid-leak are contained in a small metal box (giving effective screening), while a larger wooden cabinet houses the batteries, galvanometer, potentiometer, control switches and milliammeter for adjusting the current through the valve filaments. The arrangement is shown in Fig. 12, and it will be seen that the circuit is almost identical with that shown in Fig. 11. In

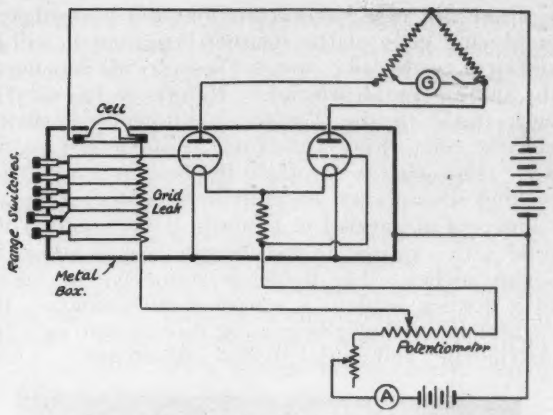


Fig. 12.—The G.E.C. Illumination Photometer.

the instrument as it was exhibited six ranges were provided by means of plungers which operated short-circuiting switches across sections of the grid-leak. It is understood, however, that alternative methods of varying the range are at present being tried, particularly the use of a variable aperture shutter or a variable density wedge over the photo-electric cell. The cell is a specially designed model of the K.M.V.6 cell (thin-film potassium on silver) operating on 10 volts. This cell obeys the cosine law very closely, i.e., its response is independent of the angle of incidence of the light over a wide range. In this respect it is said to be superior to the opal glass test plates frequently used for visual illuminometers. The valves are also of a special type with very high-grid insulation and operating with an anode potential of about 6 volts and a filament current of 0.1 amp. at 1 volt.

The procedure to be followed in making a measurement of illumination with this instrument is similar to that described above in the case of flux measurement. After the current through the valve filaments has been adjusted by means of the milliammeter A, the photo-electric cell is covered and the galvanometer G is brought to zero by adjusting the position of the movable contact on the resistance arm of the bridge, the potentiometer being at zero reading. The cell box is then placed so that the photo-electric cell is in the position at which the illumination is to be measured and the cell is uncovered. The balance of the bridge is restored (and the galvanometer brought back to zero) by setting the potentiometer. The reading of the potentiometer at which the bridge is again balanced is proportional to the illumination of the photo-electric cell and is multiplied by an appropriate constant according to the particular range in use at the time.

It will be clear that the use of the Elster-Geitel type of cell for the measurement of illumination must inevitably entail the incorporation in the instrument of (i) a battery for supplying the current which passes through the cell and (ii) an amplifying device if the range of illuminations to be covered is not to be restricted entirely to higher values than those commonly met with in practice.

For this reason the use of a cell of the photo-voltaic type would seem to possess great advantages, since it does not require any battery, and the current produced by an illumination of 10 foot-candles on cells having a total area of a few square inches is sufficient to give a reasonable deflection on a portable instrument of the permanent-magnet, moving-coil type.

---

* Inst. El. Eng., *J.*, Vol. 68, p. 533, May, 1930.

† Re-standardization (i.e., the setting of the shutter or the potentiometer current) should be carried out at fairly frequent intervals if the apparatus is used continuously for a long time, because the cell-filter combination may change its sensitivity by as much as 0.5 per cent. per degree rise of temperature.

‡ See description in *Illum. Eng.*, Vol. 25, p. 80, March, 1932, and *G.E.C. Journal*, Vol. 3, p. 155, August, 1932.

There are now several illumination photometers employing cells of the rectifier type, but it will be sufficient to describe one of these, as all depend on the same general principle. Reference has already been made to the Weston "Photronic" photo-electric cell. Fig. 13 shows a single cell, while Fig. 14 shows the complete instrument as used for making illumination measurements. Two cells are connected in parallel in a single holder so that the total area exposed to the illumination is about 3.4 square inches. The holder is connected by means of a flexible lead to a sensitive milliammeter, the current from the cells passing directly through the instrument and an external resistance. Three

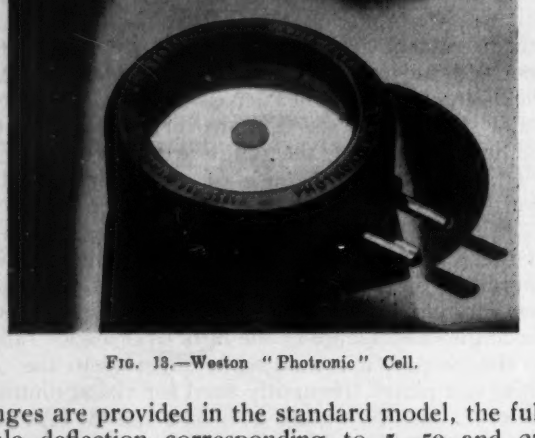


Fig. 13.—Weston "Photronic" Cell.

ranges are provided in the standard model, the full-scale deflection corresponding to 5, 50 and 250 foot-candles respectively. These ranges are obtained by shunting the milliammeter, a three-way switch being provided for this purpose. For measuring low illuminations (full-scale deflection at 1 foot-candle) the number of cells in parallel

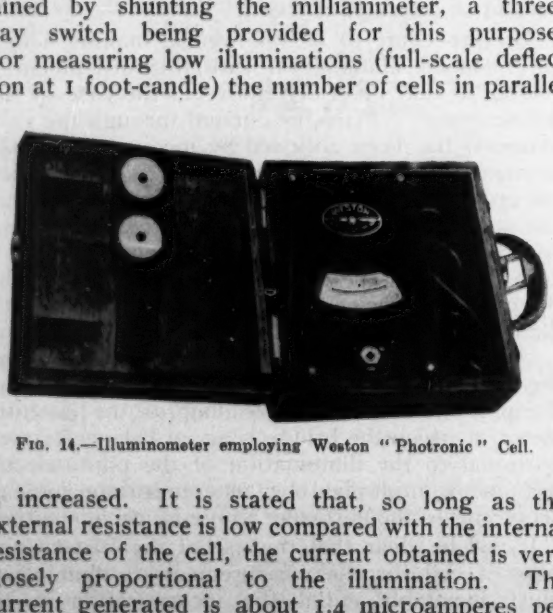


Fig. 14.—Illuminometer employing Weston "Photronic" Cell.

is increased. It is stated that, so long as the external resistance is low compared with the internal resistance of the cell, the current obtained is very closely proportional to the illumination. The current generated is about 1.4 microamperes per foot-candle, so that a pair of cells under an illumination of 5 foot-candles will give 0.014 milliampere. Actually the instrument as marketed is scaled in foot-candles.

The spectral sensitivity curve of this cell has already been given (Fig. 5, curve (*d*)), and it will be seen that its shape is not so very different from that of the visibility curve of the eye except in the shorter wavelengths. It should, therefore, be possible to obtain a correcting filter which would give a very satisfactory correction without undue loss of sensitivity. It has been stated that such a filter has been developed, but no details of its composition are yet generally available.* Its transmission factor is given as 27 per cent.

The chief disadvantage of this instrument for general purposes is its very marked departure from the cosine law. Fig 15 shows how the response of the cell changes as the obliquity of the incident light increases.† To compensate for this effect a special form of cell construction is being developed, but this is still in the experimental stage.

A somewhat similar type of cell is made by A. Pfeiffer, of Wetzlar. This is believed to consist of selenium on a lead plate, the upper electrode being a sputtered layer of gold. The sensitivity is about 3 microamperes per foot-candle, and the

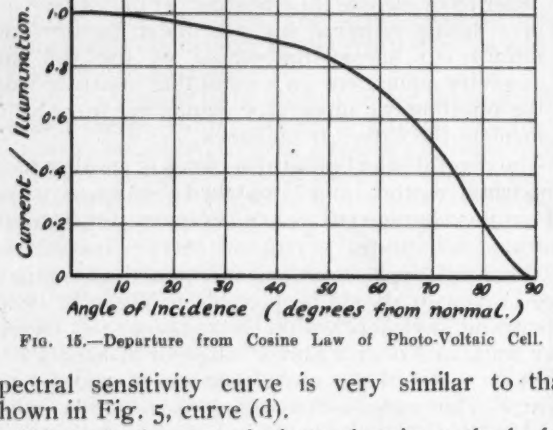


Fig. 15.—Departure from Cosine Law of Photo-Voltaic Cell.

spectral sensitivity curve is very similar to that shown in Fig. 5, curve (d).

Although the use of photo-electric methods for the everyday measurement of illumination is as yet in its infancy, there can be no reasonable doubt that it is bound to develop rapidly in the immediate future.

The Determination of Polar Curves.

Although, speaking strictly, the determination of polar curves of light distribution from a lamp or fitting should be considered as a type of candle-power measurement, there is the important difference from the point of view of photo-electric photometry that it is the *shape* of the curve that is usually required, rather than exact absolute values of candle-power. Since the colour of the light is usually the same at all angles, it follows that the cell need not be screened to give an exact imitation of the sensitivity curve of the eye.

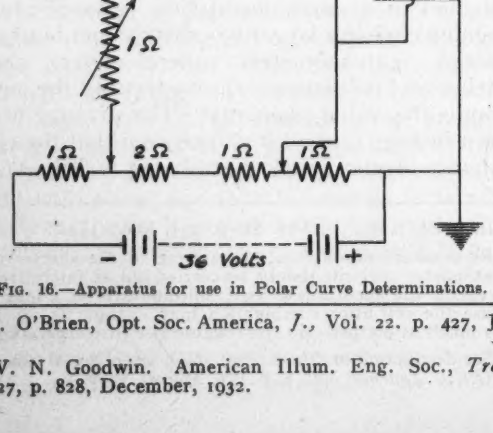


Fig. 16.—Apparatus for use in Polar Curve Determinations.

* B. O'Brien, Opt. Soc. America, *J.*, Vol. 22. p. 427, July, 1932.

† W. N. Goodwin. American Illum. Eng. Soc., *Trans.*, Vol. 27, p. 828, December, 1932.

The very simple circuit shown in Fig. 16 is used at the Holophane Research Laboratories for work of this kind. The usual form of mirror apparatus used for polar-curve work reflects the light from the fitting to the caesium thin-film cell C. The cell is only exposed to the light during the time required to make an observation; in the intervals, while the mirrors are being moved, the case containing the cell is closed by means of a shutter. The light entering the cell passes through (i) a special glass filter which cuts out all infra-red and ultra-violet radiation, and (ii) an iris diaphragm, which is used for altering the range. A measurement is made at any given angle by opening the shutter and reading the deflection of the needle of the Lindemann electrometer E.

An instrument which can be used out-of-doors for measuring the candle-power of, say, a street lamp as viewed from any given point has been described by L. T. Minchin before this Society.* An image of the lamp is formed by means of a lens on the sensitive surface of an Elster-Geitel cell, and the resulting current is measured by means of a liquid high resistance and a Lindemann electrometer.

The Recording of Illumination Curves.

A very useful application of the photo-electric cell is in the preparation of photographic records of a varying illumination or of polar-curves of light distribution. It is only necessary to amplify the current passing through the cell and cause this amplified current to deflect a galvanometer spot which falls on a piece of photographic paper. This paper either travels in a direction at right angles to the line of motion of the spot or else it rotates about an axis coinciding with the beam of light forming the spot when this is undeflected. The general principles will be obvious, and for details reference may be made to papers recently published on the subject.†

Apparatus of this kind, using a copper-oxide photo-voltaic cell (manufactured by S.E.R.P.I., of Puteaux, France) is in regular use at the Laboratoire Central d'Electricité at Paris for polar-curve determinations. A polar curve, like that shown in Fig. 17, can be obtained in from five to ten minutes with this apparatus.

Other Applications of Photo-electric Cells in Photometry.

There are a number of other photometric problems in which photo-electric cells have found useful application. Among these may be mentioned the measurement of transmission and reflection factors. This requires only the measurement of the ratio of two luminous intensities (or brightnesses), and provided that either there is no colour difference involved, or else the cell is corrected by means of a filter, the method may be made very sensitive and convenient in use.

In spectrophotometric work, particularly the determination of spectral transmission curves for coloured media, photo-electric methods can be, and frequently are, used since no colour-difference is involved. This class of work, however, can scarcely be regarded as coming within the range indicated by the title of this paper.

The colour-matching of lamps‡ may be carried out very quickly and accurately by using two different cells, one specially sensitive in the red end of the spectrum and the other in the blue. If the currents through which these two cells are balanced when both are exposed to the light from a lamp L_1, say, the balance will be disturbed if it is replaced by a lamp L_2 giving light of a different colour, and the apparatus may be designed to detect differences which are too slight to be detected visually.

In the control of lamp manufacture the use of photo-electric cells has been extended beyond the simple measurement of the luminous flux output of lamps. An instrument has been described§ in which the efficiency of a lamp, in lumens per watt, is measured in a single operation, while in Germany an automatic lamp-sorting machine is being used.‖ This machine, which depends on relays operated by the current from a photo-electric photometer, divides lamps into two classes, viz., those that fall within specification limits and those that do not.

A portable apparatus for comparing the light-output from two lamps of the same size and type has been devised for demonstration purposes.**

Of the many other uses of photo-electric cells in the less familiar branches of photometry, e.g., microphotometry, stellar photometry, colorimetry, etc., it is impossible to deal, even briefly, in the present paper, and, as stated at the start, no attempt will be made even to mention the multitude of non-photometric applications of what has been so aptly termed " the valve that works by light."

Acknowledgments.

This outline, brief as it is, of the different methods of photo-electric photometry now in daily use, both in this country and abroad, has only been made possible by the cordial help which the author has received from several of those who have made a special study of the subject. In particular he would like to express his most grateful thanks to Dr. S. English, of Messrs. Holophane Ltd., to Mr. G. T. Winch, of the Research Laboratories of the G.E.C., to Messrs. Standard Telephones and Cables Ltd., and to his colleagues, Mr. J. S. Preston and Mr. L. H. McDermott. It is only due to the unremitting labour of these and other research workers in the field of photo-electric photometry that we find ourselves to-day in possession of an instrument the lack of which was regretted many years ago by that pioneer of illuminating engineering, Johann Heinrich Lambert.†† His longed-for photometer " analogous to a thermometer " is now an accomplished fact, not yet fully developed, it is true, but undoubtedly destined to find wider and wider application in that branch of metrical science which we call photometry.

---

* *Illum. Eng.*, Vol. 23, p. 280, November, 1930.

† " The Photographic Recording of Daylight." L. H. McDermott and C. J. MacManus. *Illum. Eng.*, Vol. 25, p. 41, February, 1932. (Daylight illumination is sufficiently intense to render amplification of the photo-electric current unnecessary.)

" Apparatus Directly Visualizing the Complete Light-distribution Curve." M. Horioka, Electrotech. Lab., Tokyo, Researches, No. 268, August, 1929.

C. Müller, Z.techn.Physik, Vol. 9, p. 154, 1928.

‡ See N. R. Campbell and G. W. B. Gardiner, *J. Sci. Insts.*, Vol. 2, p. 177, 1925.

G. T. Winch, *idem*, Vol. 6, p. 374, 1929.

§ G. T. Winch and C. T. Harper, *G.E.C. Journal*, Vol. 3, p. 149, August, 1932.

‖ W. W. Loebe and C. Samson, *E.T.A.*, Vol. 52, p. 861, July, 1932.

** *Eclairage et Force Motrice*, p. 1005, December, 1932.

†† " Photometria," pars 1, cap. 1, §11.

Discussion

Lt.-Col. KENELM EDGCUMBE opened the discussion by congratulating the author on his paper. He was pleased to see the introduction of definite names to designate the various types of cell, and he particularly liked the term " photo-voltaic " for the type of cell often called " the rectifier " cell. He hoped that it would be possible to find a new name for the Elster-Geitel type, and he very tentatively suggested the name " photo-impedance cell." He thought that the photo-voltaic type showed considerable superiority over the Elster-Geitel type, because it avoided the complication always introduced by the need for an external battery. The departure from the cosine law was a matter of importance in such problems as street lighting, but for much ordinary work the trouble due to this effect was not serious. There was a particular application of the cell in which the trouble could be entirely eliminated, viz., its use in conjunction with a photometric integrator. He showed a cubical integrator in which a Weston cell was placed close to the opal glass window. Under these conditions it was a very simple matter to make measurements of the luminous flux. So long as the test lamp and sub-standard used did not differ very widely in colour, the spectral characteristics of the cell were comparatively unimportant.

Mr. G. T. WINCH agreed that the photo-voltaic cell was very convenient for many purposes, but its use was at present restricted to the higher ranges of illumination, i.e., from 1 foot-candle upwards. For lower illuminations than this it was necessary to use the Elster-Geitel type of cell, so that an amplification system could be employed. The author had painted rather a dark picture as regards the precautions necessary in the use of the Elster-Geitel cells, but recent work had helped matters considerably in this respect. In particular, a unit had been developed in which the photo-electric cell, a grid leak, and one of the valves were mounted in a single glass container, which could be covered with a metal shield, the whole being thus completely freed from external disturbance. The valve used was of a special type requiring 6 volts for the high tension and taking 1 volt on the filament. Further, it was possible to use a circuit including only one valve instead of two, and this produced a considerable simplification.

Mr. L. T. MINCHIN said that in his opinion it was important that the photo-electric cell should obey the cosine law, if it was to be used in place of the window in a photometric integrator, because much of the flux reaching it would be incident at a very oblique angle. He asked the author whether, in his opinion it was possible to use a cell in this way, or whether it would have to be placed in some auxiliary sphere or cube? The latter arrangement involved a considerable loss of light. He pointed out that the photo-voltaic cell showed a high sensitivity at the short wavelength end of the spectrum, and he enquired what was the nature of the filter which could be used to correct this.

Mr. J. S. PRESTON said that it was useful to have a survey of progress in the subject from time to time. In his opinion, there was little to choose between the Elster-Geitel cell and the photo-voltaic cell as regards spectral sensitivity or proportionality between the current and illumination. A very important matter from the practical point of view was the effect of temperature, and he enquired what was the change of sensitivity produced by a given change of temperature in the case of a photo-voltaic cell?

Mr. H. BUCKLEY said that although it was clear that the photo-electric cell possessed at least as many disabilities as the human eye, it had nevertheless established itself for photometric work to commercial accuracy. Whether it would ever establish itself for high-precision photometry remained to be seen. A cell could never be made to reproduce the results given by the average eye, but, of course, it was true that no *single* eye was identical in its characteristics with the average eye. In flicker photometry it was possible to make tests of each individual eye (by means of a yellow and a blue filter) and to correct the results obtained by this eye so as to get the results which would be given by the average eye. Possibly some analogous process might be found for precision work with photo-electric cells.

Mr. A. E. AVENT said that a colour filter had been developed for use with the Weston " Photronic " cell, but although this gave a good correction it was found to be unstable. Work was still in progress, and he expected that very soon a stable filter giving adequate correction would be available.

Mr. E. STROUD said that he thought the paper gave an excellent survey of the subject, and should do good work in encouraging the use of photo-electric methods of photometry.

Mr. W. HOLMES asked whether it would be possible to treat the surface of a photo-voltaic cell in such a way as to give a closer approximation to the cosine law? Possibly the use of a diffusing cover plate might be of advantage.

The PRESIDENT said that the author had referred to methods of amplifying the photo-electric current. Would it not be advantageous in many cases to amplify the illumination by the use of a lens? In this way the illumination of the cell could be multiplied very considerably, and then the measurement could be made considerably more sensitive. It was not only photo-voltaic cells that did not obey the cosine law. The test plates used for visual photometry also erred in this respect. He himself made a practice, in street-lighting measurements, of tilting the surface until it was normal to the incident light, and then multiplying the resulting figure by the cosine of the angle of incidence.

Dr. J. W. T. WALSH, in his reply, said that the names used for the various types of cell were those which had been quite commonly employed in the literature of the subject. He was glad that Mr. Winch had referred to the single unit combining cell, grid leak and valve. There was no doubt that this unit was extremely convenient, and would materially simplify the use of photo-electric cells for photometry. Referring to Mr. Minchin's question, he said that, in his opinion, it would not be advisable to use a cell which departed completely from the cosine law as a substitute for the window in a photometric integrator. It could, however, be placed close behind the window, as in the case of the instrument shown by Colonel Edgcumbe. The temperature coefficient of the sensitivity of photo-voltaic cells had been stated to be about 1 per cent. for every 5° C. He quite agreed with the President that when it was necessary to make measurements with the light incident very obliquely, the only satisfactory way was to measure at normal incidence and multiply by the cosine. Finally, he referred to an exhibition of photo-electric cells being arranged at the Science Museum, South Kensington.

The Annual Dinner of the Illuminating Engineering Society

(Held at the Trocadero Restaurant, Piccadilly Circus, London, W.C., at 7-30 p.m., on Tuesday, February 7th, 1933.)

Photo by Rawood Ltd.

The above photograph was taken during the Dinner without the aid of flashlight. In the background, the President (Lieut.-Commander Haydn T. Harrison, M.I.E.E., R.N.V.R.) is seen standing. Mr. James Swinburne is on his left, and further to the left are Mr. and Mrs. R. A. Chattock, Sir Joseph Petavel, and Mr. Sydney Tatchell and Miss Tatchell, and Mr. T. P. Wilmshurst; on the right are Mrs. Swinburne, Mr. Ralph E. Gibson, Mrs. Haydn T. Harrison, Lieut.-Col. Kenelm Edgcumbe, Mr. and Mrs. Harold Davies, Mr. and Mrs. D. R. Wilson, and others.

THE annual dinner of the Illuminating Egineering Society took place at the Trocadero Restaurant, Piccadilly Circus, on Tuesday, February 7th, and proved once more to be a very pleasant gathering. It will be recalled that at the corresponding dinner in 1932 the attendance passed the 200 mark for the first time in the history of the Society. On the present occasion the number present (218 according to the table plan) was again a record. One foresees that the time is not far distant when it will be necessary to remove this annual event to a room of greater dimensions!

The President (Lt.-Commander Haydn T. Harrison) and Mrs. Harrison attended to welcome the guests. As usual, both gas and electric lighting were well represented. Amongst those present may be mentioned: Mr. A. W. Beuttell (Vice-President), Mr. L. E. Buckell, Mr. H. Buckley, Mr. G. Campbell and Mrs. Campbell, Mr. R. A. Chattock and Mrs. Chattock, Mr. A. C. Cramb and Mrs. Cramb, Mr. Harold Davies (President of the Association of Public Lighting Engineers) and Mrs. Davies, Mr. J. S. Dow (Hon. Secretary), Miss M. Dow and Mrs. M. F. Dow, Mr. R. S. Downe, Lt.-Col. Kenelm Edgcumbe (Past President), Col. C. H. Silvester Evans and Mrs. Evans, Mr. Ralph E. Gibson (President of the Institution of Gas Engineers), Mr. P. Good, Miss C. Haslett (Director of the Electrical Association for Women), Mr. D. Humphrey (Director of Education, The Polytechnic), Mr. W. J. Jones, Mr. S. Lacey and Miss Lacey, Mr. C. A. Masterman, Mr. W. McClelland (Director of Electrical Engineering for the Admiralty) and Miss E. McClelland, Sir Joseph Petavel (Director of the National Physical Laboratory), Mr. F. W. Purse, Mrs. Purse and Miss Purse, Mr. E. M. Severn and Mrs. Severn, Mr. A. M. Sillar (Past Chairman of the Association of Consulting Engineers), Mr. C. W. Sully (Vice-President), Mr. James Swinburne and Mrs. Swinburne, Mr. Sydney Tatchell (Vice-President of the Royal Institute of British Architects) and Miss Tatchell, Lt. Col. W. A. Vignoles and Mrs. Vignoles, Mr. T. P. Wilmshurst (Electricity Commission), Mr. D. R. Wilson (Past President), Mr. H. T. Young and Mrs. Young.

Amongst the few who were, at the last minute, unavoidably prevented from being present may be mentioned Professor E. W. Marchant, who, as President of the Institution of Electrical Engineers, had consented to respond to the toast of "The Guests." Professor Marchant sent a message expressing regret at inability to attend and conveying good wishes for a successful evening.

The usual loyal toast having been honoured, the toast of "The Illuminating Engineering Society" was proposed by Mr. JAMES SWINBURNE, F.R.S., M.Inst.C.E., M.I.E.E.

"THE ILLUMINATING ENGINEERING SOCIETY."

Mr. Swinburne's address contained many humorous references to the early days of electric lighting, notably one occasion on which a demonstration of Swan's first incandescent lamp was being arranged at Newcastle-on-Tyne, to be witnessed by H.R.H. the Prince of Wales, who was on his way north. The demonstration, however, took some time to arrange,

and when it was complete a message came through that the Prince was now on his way to Edinburgh! Mr. Swinburne also told some amusing tales of his experiences when he was a dynamo designer for Crompton's. They had all learned much since that date, but he himself realized more fully than ever how little he still knew.

Mr. Swinburne concluded by expressing his appreciation of the hospitality of the Society, and by wishing it enduring success and prosperity.

The PRESIDENT (Lt.-Commander Haydn T. Harrison, M.I.E.E., R.N.V.R.), in responding, alluded to the early days of lighting, with which Mr Swinburne's name was so closely linked. In those days much exceedingly difficult and valuable pioneering work had been done alike in the fields of gas and electric lighting. Mr. Swinburne had not mentioned all his activities. He (the President) recalled Mr. Swinburne's unique connection with the Law—he was almost equally familiar with the legal world and with the world of science.

Illumination and the Illuminating Engineering Society had both made good progress during the past year. He might perhaps single out two developments of special interest—the application of photo-electric cells to photometry and the development of the hot-cathode electric luminous discharge lamps. The programme of the Society had included addresses on both these topics. The illuminating engineer, however, was in a special position in that he had to deal with the psychology of lighting. which seemed destined to become more complex year by year. He had not merely to furnish a specified illumination in foot-candles, but to satisfy the consumer's tastes as well. The Society had enjoyed a successful year. There was a satisfactory growth in membership to record, and the Society had been perhaps exceptionally successful in realizing its aim of promoting the co-operative spirit between lighting experts of different types. A notable illustration was afforded by the visits arranged, firstly to the G.E.C. Research Laboratories at Wembley, and secondly to those of the Gas Light & Coke Company at Watson House—visits of great interest which enabled one to appreciate the great strides being made in both industries. He also wished to mention the series of lectures on illumination, about to be delivered by members of the Society. The first lecture was to be delivered on the following evening at the Polytechnic, whose Director of Education, Mr. D. Humphrey, he was glad to see present.

Members of the Society were interested not merely in the problem of producing light, but in seeing that this light was used to the best advantage. In this connection he would like to recall some words from his Presidential Address, when he stated that every illuminating engineer had it in his power to brighten the lives of many people, and that everything possible should be done to brighten the lives of those in humble homes and moderate circumstances, whose needs were apt to be overlooked.

The President referred to the serious illness of his predecessor, Sir Francis Goodenough. Members had recently learned with satisfaction that he was now well on the way to recovery. (Applause.) In conclusion, the President mentioned that the attendance at the present dinner was again a record. He wished to convey to the Hon. Secretary and his staff their appreciation of the hard work that had led to this successful issue.

"THE GUESTS."

The toast of " The Guests " was proposed by Mr. A. W. BEUTTELL, M.I.E.E., who, in welcoming many familiar friends, remarked that the spirit of fellowship characteristic of the Society was surely one of the most pleasant things in life. The Society should feel pride in such a gathering, including representatives of kindred societies, linked by a species of family bond.

He wished first to mention Mr. Swinburne, an old family friend, much interested in this comparatively young Society, who had lectured before them last year. He wished next to welcome Mr. R. E. Gibson, the President of the Institution of Gas Engineers. They had also looked forward to the presence of the President of the Institution of Electrical Engineers, Dr. W. E. Marchant. He had been unfortunately prevented from being present, but had sent his best wishes for a successful gathering. These two bodies might be regarded as parents —as the father and mother of the Society. Father was a good deal older than Mother, but both had always been good parents. Then there was an Uncle, much older than either Father or Mother— the Royal Institute of British Architects—whose Vice-President, Mr. Sydney Tatchell, was amongst them again. The Institution of Public Lighting Engineers, whose President (Mr. Harold Davies) was present, might surely be regarded as a younger brother, seing that both bodies had the same " nanny," in the person of their Hon. Secretary (Mr. J. S. Dow). Mr. Davies was one of those who had devoted a great deal of effort to the British Standard Specification of Street Lighting. He had also to welcome a familiar friend in Sir Joseph Petavel, the Director of the National Physical Laboratory. Amongst others whom they were pleased to see present he might also mention Mr. A. M. Sillar (a Past Chairman of the Association of Consulting Engineers), Mr. D. Humphrey (Director of Education at the Polytechnic), and Miss Caroline Haslett, a member of the Society who also was the Director of the Electrical Association for Women. He desired to wish all of them a thoroughly enjoyable evening.

Mr. RALPH E. GIBSON, M.Inst. Gas Engrs. (President of the Institution of Gas Engineers), said that he felt it a heavy responsibility to reply to the toast. He did, however, appreciate the honour—the more so as it gave him an opportunity to say how much the Institution of Gas Engineers appreciated the work of the Illuminating Engineering Society, with which they were very pleased to be associated. The history of lighting was as old as creation. Men, even in very early days, were no longer content with natural light and sought to convert night into day—therefore the craft of the illuminating engineer was indeed an old one. He was gratified at having his name associated with the toast, and wished to express his thanks for the hospitality of the Society. He was sure that all the guests were enjoying themselves immensely.

Mr. SYDNEY TATCHELL, F.R.I.B.A. (Vice-President of the Royal Institution of British Architects), likewise expressed his pleasure at being present. He could assure them that architects desired to be included in " the family." They were making definite efforts to contribute their share to the common fund of experience. They had themselves been instrumental in assembling a family conference, as a result of which a committee connected with the building trades and professions was in course of formation, and assuredly the lighting industry would not be left out. He hoped that the architects were thus setting a good example, and showing themselves worthy to be included in the family group. He, too, wished to say how very much he appreciated the hospitality and entertainment of the Society.

As usual, the speeches terminated at an early hour, the remainder of the evening being devoted to dancing and social intercourse.

The Effect of the Spectral Transmission of the Atmosphere upon Visibility by Artificial Light

By M. G. BENNETT, M.Sc., F.Inst.P.

Introduction.

THE question of whether light of one colour is better than another (and if so, how much better) in the case of searchlights, motor-car headlights, beacons and navigation lights, is of scientific as well as practical interest, and is a question in which a large number of people are interested. This paper is an attempt to solve these problems as far as the data available permit. In many cases, conclusions may be drawn which are as definite as practical requirements demand.

The first part of the paper consists of a discussion of the available information on the scattering and transmission factors of the atmosphere for light of different wavelengths. The discussion is restricted to data obtained from experiments on the atmosphere itself.

Experiments on artificial clouds and fogs in enclosed chambers have so far led to no conclusion which can be applied with certainty to the atmosphere; indeed, the results of these experiments appear to be inconsistent in some respects. Further, extrapolation from small scale to field conditions is difficult, owing to doubt about the composition of atmospheric obscurity, and to the great difference between the dimensions of the two sets of conditions. For these reasons the information derived from laboratory experiments is not used in this discussion, though such experiments will no doubt lead to valuable information when they are further developed.

Mathematical theory also has so far yielded no result which can be applied generally. Atmospheric obscurity consists of drops and/or particles which may be of diameters up to say 20μ, and the sizes may not be uniform. It is only when the particle size is small compared with the wavelength of light (i.e., small compared with say 0.5μ) that theory provides a complete solution. When the particles are comparable with, or greater than, the wavelength of light, theoretical solutions for particular cases are so far all that have appeared. In view of the complex nature of atmospheric obscurity, such solutions are of little value for the present purposes.

Summary of Data.

Transmitted Light.

In Fig. 1 are summarized the data given by Link and Hugon (*Comptes Rendus*, 190, p. 810, 1930), Buisson, Jausseran and Rouard (*Comptes Rendus*, 190, p. 808, 1930), Benford (*Gen. Elect. Rev.*, 29, p. 873, 1926), and Granath and Hulbert (*Phys. Rev.*, 34, p. 140, 1929). As is to be expected, the absolute values of the transmissions are different in the six cases. In order to compare the rates of change of transmission with wavelength for the six cases, the data are represented in a different fashion in Fig. 2. In each case the thickness of atmosphere has been calculated for which the transmission of $\lambda = 0.555\mu$ is equal to 0.5. The transmissions of other wavelengths for these thicknesses were then computed, and plotted in Fig. 2. The slopes of the lines in this figure can be taken as representing the relative rates of change of transmission with wavelength for the six cases.

Besides the above quantitative data, there exists some qualitative information. Karrer and Tyndall (Bureau of Standards, Scientific Papers, 16, p. 377, 1920), found that transmission increases with increasing wavelength up to about $\lambda = 0.6\mu$ (the exact value depending on the weather conditions), but thereafter there is a tendency to decrease. Foulke (Am. Ilum. Eng. Soc., *Trans.*, 24, p. 384, 1929) states that there is a maximum of transmission at $\lambda = 0.65\mu$. Buisson, Jausseran and Rouard say that in fog the absorption per unit thickness is greater,

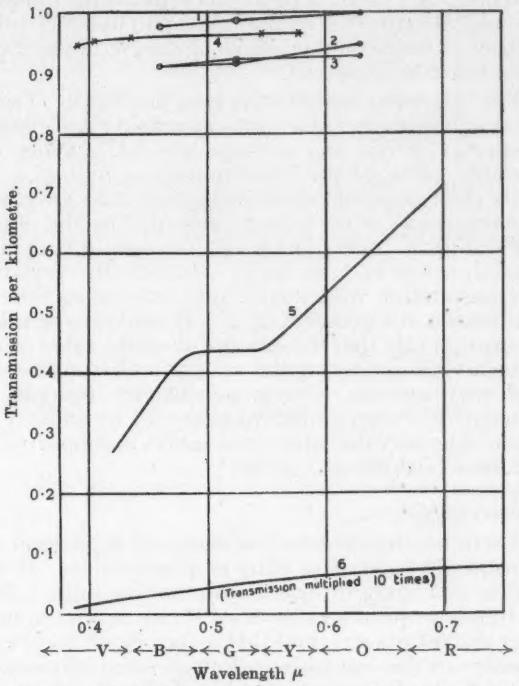


FIG. 1.—Relation between Transmission and Wavelength.
Curves 1, 2 and 3, Link and Hugon.
Curve 4, Buisson, Jausseran and Rouard.
Curve 5, Benford.
Curve 6, Granath and Hulbert.

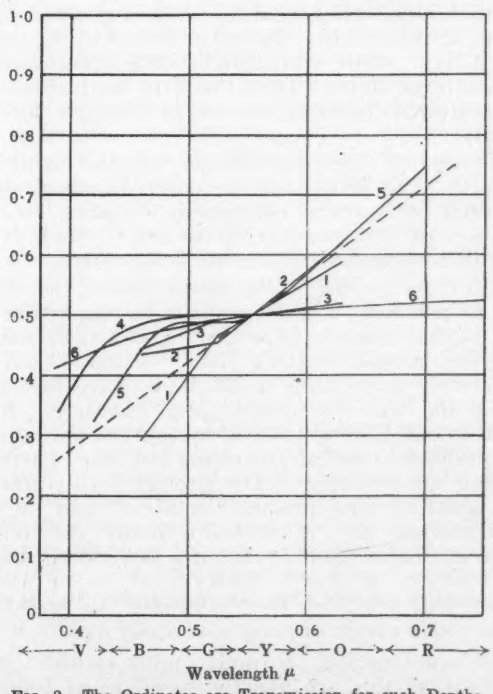


FIG. 2.—The Ordinates are Transmission for such Depths of Atmosphere that the Transmission of Wavelength 0.555μ is, in each of the six cases, equal to 0.5.
Curves 1, 2 and 3, Link and Hugon.
Curve 4, Buisson, Jausseran and Rouard.
Curve 5, Benford.
Curve 6, Granath and Hulbert.

but there is less variation with wavelength than in the clear air case shown in Figs. 1 and 2.

In considering the above data it must be remembered that the modes of formation of atmospheric obscurity are many, and rarely will any one state of obscurity be exactly repeated as regards the number, size and constitution of particles, and in every other respect. Hence the variations, apparent in the above data, must be expected.

The following conclusions may be drawn: Transmission always increases with increasing wavelength up to $\lambda = 0.65\mu$, and perhaps beyond. When the absolute value of the transmission is high (i.e., in fairly clear weather) the transmission may vary with wavelength as much as is represented by the dotted line in Fig. 2. When the absolute value of the transmission is low (i.e., in foggy weather) the variation of transmission with wavelength may be as little as that shown in Curve 6, Fig. 2. It may also be taken as a rough rule that the less the absolute value of the transmission the less is the variation of transmission with wavelength. Assuming that the decrease in transmission is accompanied generally by an increase in particle size, the latter conclusion is supported by the theory, as far as it goes.

Scattered Light.

There are fewer data for scattered light than for transmitted light, and none is quantitative. It is a matter of common observation that daylight falling on thin haze produces a veil of bluish scattered light over distant objects, and that a very dense fog never appears to the eye to be coloured when illuminated by the light of, say, a motor headlight.

The attenuation of a beam of light passing through an obscuring atmosphere is due, not so much to true absorption, but to loss by scattering. It is to be expected, therefore, that in fairly clear weather, when, as shown in the previous section, the rate of change of transmission with wavelength is great, the transmitted light will become redder and redder as the distance travelled increases, and the scattered light will become bluer and bluer. Benford has observed this effect in a searchlight beam. On the other hand, in dense fog, when there is comparatively little change of colour of the transmitted light, there will also be little coloration of the scattered light. Thus the data on transmitted and scattered light are, as far as they go, in conformity.

As regards the distribution of the scattered light, i.e., the proportion of different wavelengths scattered in various directions relative to the direction of transmission, there are no data at all from direct experiments on the atmosphere.

Before proceeding to the application of the above data to practice, it may perhaps be opportune to urge that systematic experiments should be undertaken to provide further data. What would be particularly interesting would be to have measurements on the transmitted and scattered light together with simultaneous measurements of the size, number and composition of the particles forming the obscurity. The subject is of considerable academic and practical interest, and on the experimental side it involves many difficulties. These attributes should make it a fascinating study.

Application of the Data to Visibility Problems.

The visual range of point sources of light.

The fundamental formula upon which such problems as this are usually based is as follows. The illumination on the eye, when the source is at its visual range, is

$$I t / D^2 = k \quad \text{..... (i)}$$

where

- I is the intensity of the source,
- t is the transmission factor of the atmosphere, for the depth D of atmosphere,
- D is the visual range of the light-source,
- k is the minimum illumination perceptible to the eye.

This equation has been solved below for a number of different cases, and the answers are tabulated at the end.

Case I. Source with a continuous "white" spectrum.

Consider a source at a colour temperature of 3,000° A. Its colour will correspond with sufficient accuracy to that of a high-efficiency electric lamp. Applying the luminosity factor, we get the curve shown in Fig. 3, representing the distribution of luminous energy in the beam at the source.

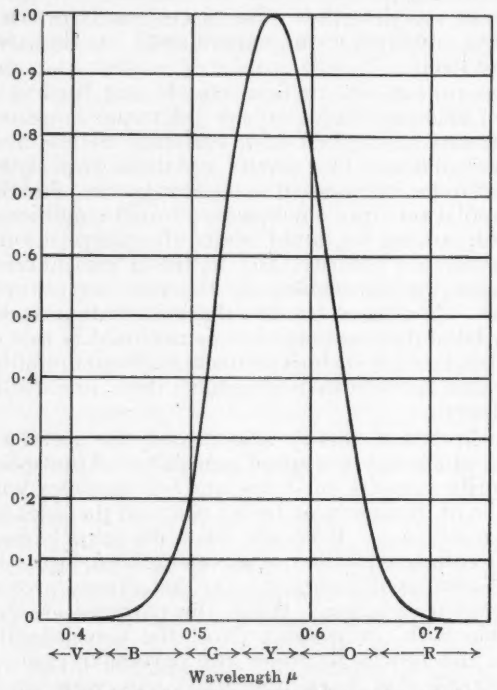


FIG. 3.—Distribution of Luminous Energy in a Light-source at a Colour-temperature of 3,000° A.

We now require to know the intensity of illumination and the wavelength-distribution of luminous energy at various distances from the source. Two types of atmosphere are taken as examples:

1. Transmission/km. (for $\lambda = 0.555\mu$) = 0.95.
   Rate of change of transmission with wavelength, as shown by dotted line in Fig. 2.
   These conditions are taken as typical of fairly clear weather.
2. Transmission/km. (for $\lambda = 0.555\mu$) = 0.0055.
   Rate of change of transmission with wavelength, as shown in Curve 6, Fig. 2.
   These conditions are taken as typical of fog.

The required information was computed from the following formula:

$$E_\lambda = \frac{I_\lambda \tau_\lambda^d}{d^2} \quad \text{..... (ii)}$$

where

- E_λ is the illumination of wavelength λ,
- I_λ is the intensity of wavelength λ emanating from the source,
- τ_λ is the transmission per unit distance for wavelength λ,
- d is the distance from the source.

Solving this equation for various values of λ and d, we get a series of curves, roughly similar to Fig. 3, representing the intensity and distribution of energy in the light as it radiates from the source. The amplitudes of the curves diminish, and the maxima shift towards the red end of the spectrum, as the distance from the source increases. Curves showing the total illumination due to all wavelengths, and the position of the maxima, for various values of d, and for sources of a million and a hundred candle-power, are given in Figs. 4 and 5.

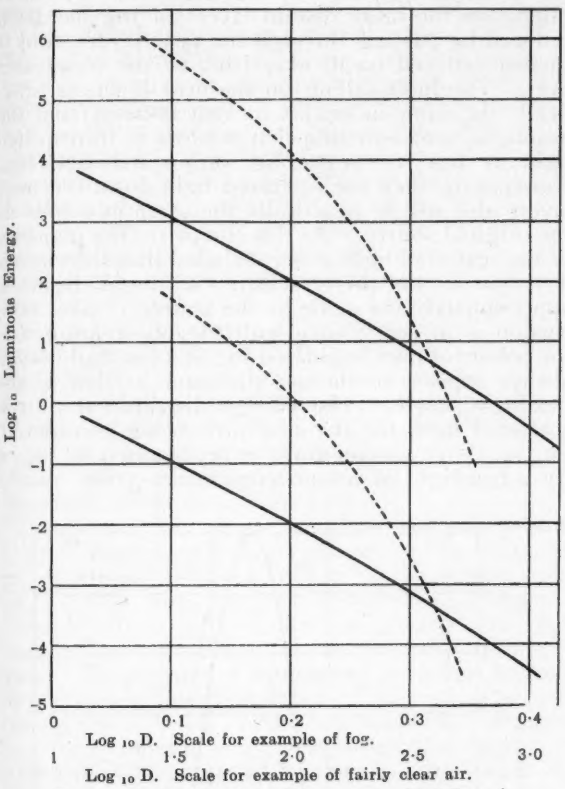


FIG. 4.—Showing Luminous Energy transmitted through (*a*) fog and (*b*) fairly clear air.

———— Curve for fog.

---------- Curve for fairly clear air.

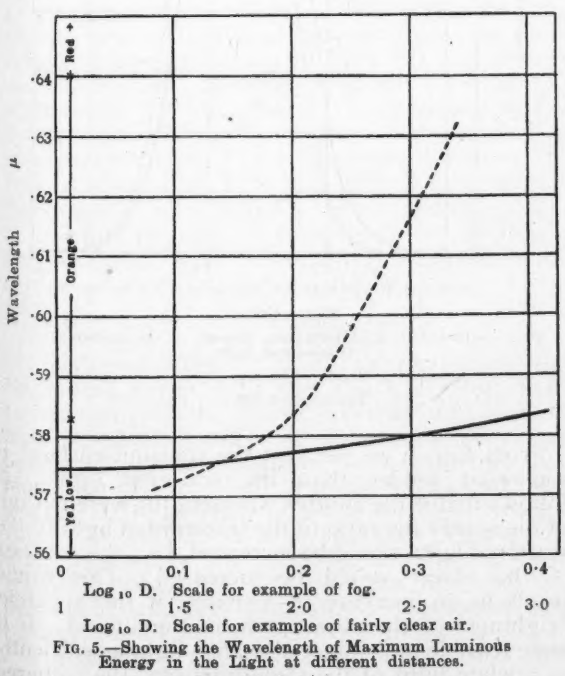


FIG. 5.—Showing the Wavelength of Maximum Luminous Energy in the Light at different distances.

———— Curve for fog.

---------- Curve for fairly clear air.

We now come to the question of the value of k (the threshold) to be used in equation (i). A number of different values have been given in the literature, and it is obvious that in different circumstances different values of k will apply. Since, however, the present purpose is to give illustrative examples, and not a general solution, it may be assumed that k is a constant for any given wavelength. Foveal vision only is considered. The following values are adopted:—

Green light	5 c.p./km².
White light	0.2 c.p./km².
Red light	0.2 c.p./km².

(In the case of green light, a smaller illumination than the above can be seen, but it appears white.)

The results of the calculations described above are summarized in the accompanying table:—

TABLE I.

Weather example	I c.p.	Visual range D km.	Wavelength of maximum intensity as it appears to observer at distance D
Foggy	10^6	2·6	0·584μ just in orange
	10^3	1·2	0·575μ yellow
Fairly clear	10^6	230	0·6065μ orange
	10^3	17	0·570μ yellow

The wavelength of maximum visual energy in the source is 0.567μ. The luminosity function falls off so rapidly towards the red end of the spectrum that, in spite of the better transmission of the longer wavelengths, the maximum wavelength for the light received by the observer is in no case greater than 0.6065μ, which is in the orange. A source at a lower colour temperature than that considered here would of course appear redder than this, because it is redder at the source, but it is not anticipated that the change in colour produced by the atmosphere would ever be much different from the changes given here for lights of these intensities.

The question of what energy-wavelength distribution of a light will give the greatest range for the least input of energy into the source is very largely a matter of the over-all efficiency of various methods of light production. It is not proposed to go into this point in great detail here, but the following example may be of interest.

If all wavelengths below 0.525μ were cut out of the source (the source being otherwise unaltered) the light (at the source) would appear a deep yellow, and the intensity would be cut down by 13 per cent. Let us consider an atmosphere with mean transmission factor the same as in the fairly clear air specified above, but suppose the transmission of all wavelengths is the same. The reduction of intensity of 13 per cent. would then result in a 2.2 per cent. reduction in range. But actually the fairly clear atmosphere specified above would cut out most of the short waves before they reached the observer, so that cutting out these wavelengths at the source would have very little effect on what the observer sees, and the range would actually be reduced by 0.4 per cent. only.

Case II. Monochromatic sources.

By the same process that was used for the above examples, the visual ranges of certain monochromatic sources have been computed. The results are shown in Table 2.

TABLE II.

Weather example	$\lambda\mu$	I c.p.	Visual range, D km.
Foggy	0·5 green	10^6	1·98
		10^2	0·69
	0·7 red	10^6	2·74
		10^2	1·18
Fairly clear	0·5 green	10^6	104
		10^2	4·2
	0·7 red	10^6	291
		10^2	20

In this case it will be seen that, comparing lights of equal initial intensity, the range of a red light is considerably greater than the range of a green light. In the comparatively non-selective foggy atmosphere this is chiefly due to the high value of k for green light; but in the fairly clear air example, the selective effect of the atmosphere is important, and being added to the effect of k, it results in the red 100-candle-power light being seen nearly five times as far as the green.

The visual range of objects illuminated by a beam of light at night.

This problem is entirely different from the previous one. A searchlight used in fairly clear weather, and a motor headlight in fog, are the two examples which will be discussed. In these cases the obscuring medium scatters so much light into the eyes of the observer that the atmosphere surrounding the object and forming its background appears of comparable brightness to that of the object itself. As the distance of the object increases the difference between the brightnesses of object and background becomes less and less, until it eventually reaches the limit which the eye can perceive. Scattered light is thus as important as transmitted light in this problem.

Case I. Motor headlight in fog.

Approximate information on the colour effects to be expected can be obtained in the following manner. It is obvious from the previous results that the colour changes in the transmitted light will not be great, and the following assumptions are therefore justified. Consider a fog in which a 100-candle-power white light can be seen for 25 metres. The logarithm of the transmission/km. for white light will be about -220.

The change in colour of the transmitted light, at a certain distance, increases with the density of the fog, other things being the same, so that the assumption that the fog is so very dense as stated, means that the computed coloration will be extreme. It will further be assumed that the rate of change of transmission with wavelength is again as shown in Curve 6, Fig. 2. In such a dense fog as this it is very unlikely that the rate of change would actually be so great. In respect of both mean transmission and rate of change of transmission, this example may therefore be taken as an extreme case, and the computed coloration is never likely to be exceeded in any fog which is so dense as to interfere with road transport.

A headlight of ordinary pattern will not render objects visible to anything like as great a distance as a 100-candle-power light can be seen. It will be assumed that it renders them visible up to half the distance, i.e., in this case, 12.5 metres. If the object observed is white, the quality of light which reaches the observer, after travelling from the headlight to the target and back to the eye, will therefore be similar to the quality of the light which an observer would receive from a 100-candle-power light when he stands 25 metres away. This quality of light has been computed in exactly the same way as in the previous problems. The result is given in Fig. 6 for a headlight of colour temperature 3,000° A.

Most of the scattered light arises from the first few feet of fog near the headlight, for the light falling on the more distant layers of fog has been reduced by passing through the near layers, and is further reduced on its way back to the observer's eyes. The light falling on the near layers is practically the same in quality as that issuing from the headlight, and assuming that the loss in transmitted light is due to scattering only (and not true absorption), then the scattered light from the near layers also will be practically the same in colour as the original source. As this comprises the majority of the scattered light it is concluded that the energy distribution of the resultant scattered light is approximately the same as the source. This conclusion is in accordance with the observation that the colour of the illuminated fog in a headlight beam always appears to the eye the same as that of the headlight itself. The energy distribution of the scattered light for the case now being considered, on the above assumptions, is represented in Fig. 6 for a headlight of colour-temperature 3,000° A.

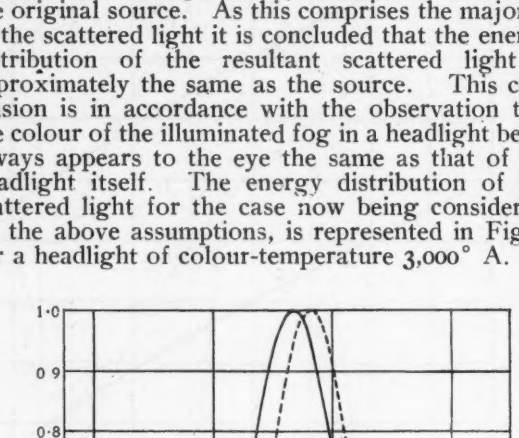


FIG. 6.—Distribution of Luminous Energy in the scattered and transmitted light.

———— Scattered light.

---------- Transmitted light.

From Fig. 6 we see that the transmitted light is somewhat redder than the scattered light. It follows that if the shorter wavelengths were cut out of the source the ratio of the transmitted light to the scattered light would be increased, i.e., the contrast of the object would be increased. This would result in an increase of visibility if the apparent brightness of the object remained unaltered. If it were feasible to produce a reddish light as efficiently as a white light of the same intensity, the coloured light would therefore give better results. But the

usual, and, as far as I know, only method of producing a coloured headlight beam is to introduce a colour filter in front of a white light projector, and such filters cut down the total illumination quite considerably. Now the contrast required to render an object visible increases as the apparent brightness decreases, so that we have to consider whether the advantage of improved contrast due to the introduction of the filter is outweighed by the disadvantage of reduced illumination due to the same agency.

The effect has been computed of introducing certain Wratten filters, which cut out the shorter wavelengths up to certain specified limits. Wratten filters are taken as good examples of high-grade filters which will produce the required coloration, while causing the least possible reduction in total illumination. By multiplying the transmission factor of the filter for each wavelength by the ordinate for that wavelength of the two curves in Fig. 6, one can readily compute the percentage change in intensity of both the transmitted light (T) and the scattered light (S); and hence also the percentage change in the ratio T/S, i.e., in the contrast. The same computation gives also the percentage reduction in apparent brightness of the target.

As pointed out above, a certain increase in contrast is necessary to compensate for the reduction in brightness, and there will be no net improvement in visibility until the actual increase in contrast brought about by the filters is greater than that required to compensate for the reduction in brightness. The method of computing the actual increase in contrast is described above. The method of computing the increase in contrast required to compensate for the loss in brightness is described below.

Walsh (" Photometry," Constable, 1926, Fig. 26), gives curves showing the way in which Fechner's fraction (i.e., the least perceptible difference in brightness divided by the brightness of the field) varies with the brightness of the field. Curves are given for various colours. They apply to large objects only. In the present example the object reflects a certain amount of light (T) into the eyes of the observer. Superposed on this is the light (S) scattered by the atmosphere. S constitutes the field brightness. When the object is at the limit of visibility, the ratio T/S is Fechner's fraction. The rate of change of $T/S_{(limit)}$ with S can therefore be computed from Walsh's curves, and the increase in contrast required to compensate for the loss in brightness will be the change in S multiplied by this rate of change, or, mathematically,

$$\triangle(T/S) = \triangle(S) \times \frac{d}{dS}(T/S) \text{ approximately.}$$

The rate of change of Fechner's fraction with field brightness varies with the absolute value of the latter, and with the colour. We do not know the absolute value of the field brightness in the present example, and computations have therefore been made for two levels of brightness which are considered to be somewhere about the right order of value. It will be seen later that the results are not much affected by the particular value used. With regard to colour, the data for white light only have been used, and the result of this procedure is to exaggerate the advantage of the filters.

The results of the above computation, for a light-source of colour-temperature 3,000° A., are given in Table 3. Exactly similar computations have been carried out for a source of colour-temperature 2,000° A., but the results are so similar to those given here that it is not thought worth while to record them in detail. Since the colour-temperatures of most modern illuminants lie somewhere between these figures, the results may be taken to apply to all artificial " white " sources.

TABLE III.

1	2	3	4	5	6	7	8	9
No. of Wratten filter interposed	λ up to which light is cut off μ	Colour of remaining light	Proportionate reduction in		% increase in T/S	% loss in brightness	% increase in T/S necessary to compensate for loss in brightness	
			Scatter S	Transmission T			@ 10^{-2} photons	@ 10^{-3} photons
—	0	white	1	1	0	0	0	0
12	0·50	yellow	0·68	0·70	3	31	4·0	6·7
16	0·52	orange yellow	0·65	0·72	11	31	4·5	7·5
22	0·55	red orange	0·42	0·51	21	53	9·1	15·1
24	0·58	red	0·23	0·31	35	73	15·3	25·5

In column 6 are shown the percentage increases in contrast due to the introduction of the colour filters described in columns 1, 2 and 3. In columns 8 and 9 are shown the percentage increases in contrast required to compensate for the reduction in brightness due to the same agency. The figure in column 6 must be greater than the figures in columns 8 or 9 before there is any net improvement in visibility. It will be seen that this condition is not satisfied unless so much of the blue is cut out of the source that the light appears at least an orange-yellow colour.

Such practical devices for the colouring of a beam as dyed rubber caps, painted bulbs, etc., involve a far greater loss in brightness for a given degree of coloration than the Wratten filters. Further, assumptions have been made in the above example, both in respect of the coloration produced by the atmosphere and the optical properties of the eye, which tend to exaggerate very much the advantage to be gained from using filters. It may therefore be concluded that the beam would have to be still more red than is found above for there to be any net improvement in visibility in practice. In fact, it would have to be so red that it would appear more like a rear-light than a headlight.

Although it may be irrelevant to this paper, it may be of interest to express a view as to what is the best arrangement of lights for driving in fog. A lamp giving a fairly narrow beam, of as great an intensity as possible, directed at the kerb at a suitable distance ahead, should be mounted as low down and as far forward as possible. The direction of vision should be at a big angle to the beam, not along it. Attention to these points will give far better results than colouring the beam will ever do.

Case II. Searchlight in fairly clear weather.

The atmosphere may be much more selective in this case than in the previous one, and both transmitted and scattered light may be markedly coloured. Owing to lack of data, and the impossibility of making such assumptions as were made in the previous case, it is not possible to come to any quantitative conclusions.

The following points may, however, be made. Messrs. Sperry have shown that the range of a searchlight increases rapidly with its intensity at low values, but the rate of increase gradually falls off, until at high values of the intensity the range is practically independent of the intensity. Now coloration of the beam generally involves a loss of intensity. One would therefore expect the effect of coloration to be most marked at high intensities, where the loss of intensity would not be felt much.

A searchlight observer stands at the side of the projector and looks through part of the beam at the target. If the observer comes nearer to the projector, his line of vision will include parts of the beam which are nearer to the projector. Now, as in the case of the headlight beam, the nearer the projector the less is the scattered light coloured. Hence the nearer the observer stands to the projector the less will be the effect of a certain degree of coloration of the beam.

SUMMARY.

Evidence is given for the conclusion that the less the mean value of the transmission of the atmosphere the less is the rate of change of transmission with wavelength. It appears that long waves are always transmitted to a certain extent better than short waves. Examples are given.

There are few data on scattered light, but what there are indicate that thin haze scatters short waves more than long, whilst a dense fog scatters all wavelengths to about the same extent.

The data are applied to the problems of the visual range of point sources of light, and of objects illuminated by the beams of a motor headlight in fog, and a searchlight in fairly clear weather. Some assumptions have to be made, but these are justified. The following conclusions are drawn:—

In the case of a light having a continuous spectrum approximating to white, intensity is a much more important factor than colour in determining its visual range, although such a light may in some circumstances appear orange from a distance. Owing to the fact that one can see a smaller amount of red light than of green light, and owing also to the selective effect of the atmosphere, it is found that a red monochromatic light is perceptible to a greater distance than a green light of equal initial intensity. The difference is greater in fairly clear weather than in fog.

The problem of objects illuminated by a beam is quite different from the above, for in this case the veiling effect of the light scattered into the eye by the particles within the beam limits the distance that the object can be seen. Given two motor headlights, differing only in colour, and not in beam candle-power, the redder of the two will give the better results. In practice, however, coloration of the beam involves a considerable loss of intensity, which tends to counteract the effect of coloration. Further, a dense fog affects all colours to very nearly the same extent. In practice, therefore, a motor headlight would have to be made orange or red before any net improvement in visibility was experienced in a dense fog.

In the case of searchlights the only conclusions drawn are that the effect of colouring the beam will be greater the higher the intensity of the beam, and the greater the distance of the observer laterally from the projector.

A Long-range Telephotometer

By Colonel C. H. SILVESTER EVANS, O.B.E., T.D., M.I.E.E., A.M.I.Mech.E., F. Inst. P., and F. WARREN CHIVERS, B.Sc.

ABSTRACT.

The paper describes a telephotometer designed for the measurement of the transmission of light by the atmosphere over ranges up to 10,000 *ft.*

In the determination of atmospheric transmission it is most important that the measurements be made over the full range, as local variations in the atmosphere may cause considerable errors if an exponential law between transmission and distance is assumed.

The instrument described gives the result as the ratio of two measurements of illumination, and does not require the employment of highly skilled observers.

IN measurements of the light distribution in beams from high-power projection apparatus it is necessary to determine the values of the atmospheric transmission factor throughout the measurements. The instrument here described was designed for that purpose (the method employed resembles that described by Benford*), and it is thought that it may have application, on a smaller scale possibly, in meteorology and illumination research.

General Description.

A uniformly illuminated screen in the form of an internally whitened box having a D-shaped aperture in one side is placed at the far end of the range and is kept at constant illumination. This illumination is measured by a suitable photometer situated near the screen. Simultaneously, by means of the telephotometer a value is obtained for the apparent illumination when seen over the given range. The transmission factor is then found as the ratio of these two illuminations.

In its essentials the telephotometer consists of a telescope and a comparison-of-brightness photometer.

The general arrangement of the instrument may be seen by reference to the diagram, Fig. 1. A schematic drawing of the optical system is shown in Fig. 2.

A large achromatic long-focus objective O is used to collect the light from the distant source, and to focus this light through stops in the telescope tube O, T, E.

The D-shaped image so formed is viewed by means of the eyepiece E. A contiguous D-shaped image of a comparison source is viewed simultaneously by the eyepiece. A measure of the apparent brightness of the distant source is then obtained by varying the brightness of the comparison source until a uniformly illuminated circular field is seen in the eyepiece.

* *Gen. Elec. Rev.*, Vol. XXII, No. 9, September, 1919, p. 668.

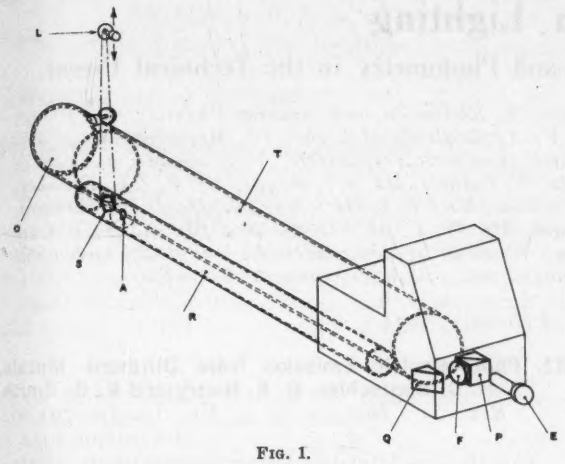


FIG. 1.

The comparison source consists of a white surface S, illuminated by a sliding lamp L. The brightness of the comparison source is determined according to the distance of the lamp L from the white surface.

The light from the white surface, after passing through a D-shaped aperture A, traverses the tube R through stops, is reflected at 90° by the prism Q, passes through the achromatic convex lens F, and after a further reflection at 90° from a silver surface within the compound prism P, it is brought to a focus in the plane of the image of the distant source and is viewed with the eyepiece E.

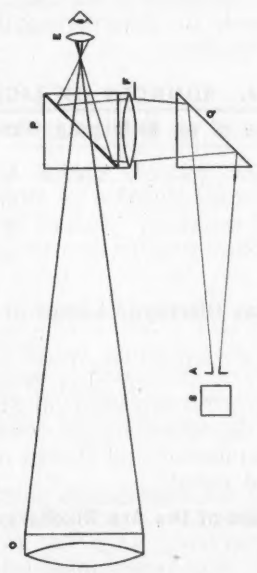


FIG. 2.

Provision is made for interposing either coloured or neutral filters in the comparison beam, when low values of transmission make it necessary. The transmission values of these filters are determined by calibration with the filters in the instrument.

It is to be noted that immediately before coming to a focus both the light from the distant source and that from the comparison source pass through the lensatic compound prism P. This prism consists of two right-angled prisms and an achromatic plano-convex lens. The principal surface of one of the right-angled prisms is silvered, with a central position left clear, and the two prisms and lens are cemented together with a very thin layer of canada balsam.

The light from the distant source passes directly through the unsilvered portion of the prism with no commensurate reflection or refraction; while the beam from the comparison source is reflected through 90° by the silvered portion.

It is essential that the optical system should be as free as is possible from all chromatic aberration, and in addition every precaution is taken to minimize surface reflection within the tubes and to prevent any stray light from reaching the observer's eye.

The alignment of the optical system is necessarily very critical. The prisms P and Q are therefore mounted on small tables provided with levelling screws, and capable of rotation, with provision for clamping firmly in position when satisfactory adjustment has been made.

Calibration.

Calibration of the instrument is conducted over an indoor range (approximately 45 feet) over which the transmission can be assumed to be 100 per cent. The distant light-source is smaller than but otherwise similar to that employed on the outdoor range; the illumination can be varied and its value is determined by means of a photometer, and then a reading taken with the telephotometer. The procedure is repeated over the required range of illumination. Then by plotting the square root of the illumination values, as measured by the photometer, against the corresponding telephotometer readings, a straight-line calibration curve for the instrument is obtained.

With a long-focus objective, as incorporated in the telephotometer, the necessary difference between the range employed for indoor calibration and that over which outdoor measurement is made involves a large movement of the objective in order to accommodate the change in focus; it becomes necessary, therefore, to apply a correction to the value of the illumination of a surface as given by the telephotometer. This correction factor, which may be considerable, is a function of the range.

If the distance from the telescope objective lens to the plane of the image is

V_1 when the telephotometer is focussed for the calibration range,

and V_2 when the telephotometer is focussed for the outdoor range,

it can be shown that the correction factor by which all illumination values as determined by the telephotometer must be multiplied to give the correct illumination values, is

$$V_2^2 / V_1^2.$$

The instrument possesses two distinct advantages:

1. Its application is very simple—the result is obtained as the ratio of two measurements of illumination without any assumption as to the relation between atmospheric transmission and distance.
2. It can be used by any observer, however inexperienced, provided that he is capable of using a comparison-of-brightness photometer.

General Assembly.

The diameter and focal length of the objective, and the disposition of the comparison source and its movement, primarily determine the bulk and weight of the instrument, which must be of sufficiently robust construction to ensure maintenance of rigidity and accuracy for employment in the field.

Acknowledgment.

The authors are indebted to Captain H. C. Gibson and Mr. E. A. H. French for their collaboration in the design of the instrument.

Literature on Lighting

(Abstracts of recent articles on Illumination and Photometry in the Technical Press)

Abstracts are classified under the following headings: I, Radiation and General Physics; II, Photometry; III, Sources of Light; IV, Lighting Equipment; V, Applications of Light; VI, Miscellaneous. The following, whose initials appear under the items for which they were responsible, have already assisted in the compilation of abstracts: Miss E. S. Barclay-Smith, Mr. W. Barnett, Mr. S. S. Beggs, Mr. F. J. C. Brookes, Mr. H. Buckley, Mr. L. J. Collier, Mr. H. M. Cotterill, Mr. j.S.Dow, Mr. J.Eck, Dr.S.English, Dr. T. H. Harrison, Mr. C. A. Morton, Mr. G. S. Robinson, Mr. J. M. Waldram, Mr. W. C. M. Whittle and Mr. G. H. Wilson. Abstracts cover the month preceding the date of publication. When desired by readers we will gladly endeavour to obtain copies of journals containing any articles abstracted and will supply them at cost.—ED.

(*Continued from p.* 54, *February*, 1933.)

II.—PHOTOMETRY AND ILLUMINATION.

57. Polar Intensity Curves can give Total Flux. E. S. Oberndorf.

El. World, 101, *pp.* 132-133, *January 28th*, 1933.

The author puts forward a method of plotting polar curves in order to obtain a direct relation between luminous flux and area on the diagram. This effect is produced by plotting the angular scale to the formula $\phi = 90^\circ (1 - \cos \theta)$, where θ is the angle at which the light is emitted, and the candle-power scale to the formula $R = \sqrt{k \times CP}$, where k is taken as the candle-power at one such radius. Curves comparing the new method of portrayal with the method at present in use are given. W. C. M. W.

58. Photometric Determination of Camera Exposures for Motion-picture Work. Alan M. Gundelfinger and Jerome W. Stafford.

Frank. Inst. J., 215, *pp.* 81-92, *January*, 1933.

A photometric method for the determination of exposures in motion-picture work is described. The relation of exposure, object brightness and lens-stop number is derived, and the proportionality constant empirically determined for "Pan Astro" lenses of two and three-inch focal length. A nomographic chart of exposure relation is given to simplify the determination of the lens-stop number to be used for a given object brightness. S. S. B.

59. An Extraordinary Photo-electric Cell. Anon.

Frank. Inst. J., 215, *p.* 68, *January*, 1933.

A short description of a photo-electric cell requiring little in the way of auxiliary apparatus. S. S. B.

60. Modern Methods of Making Photo-electric Cells. Georges Déjardin.

R.G.E., 33, *pp.* 3-13, *January 7th*, 1933; *pp.* 36-53, *January 14th*, 1933.

Gives a technical exposition of modern practice in the construction of photo-cells. Each separate portion of the cell is dealt with in great detail, special attention being given to the glass used for the envelope and the preparation of the emissive surface. W. C. M. W.

61. Note on Rating of Photo-electric Tubes. Lewis R. Koller.

Rev. Sci. Inst., *Vol.* 3, *No.* 12, *pp.* 760-761, *December*, 1932.

The author points out that to be strictly correct when tube sensitivity is specified in amperes per lumen, a filter should be used with the cell to remove the infra-red radiation. Accordingly, the most satisfactory method of rating is to specify tube sensitivity in terms of amperes per lumen when illuminated by a light-source at a given temperature. Sensitivity curves of various cells are given. F. J. C. B.

62. Photo-electric Emission from Different Metals. H. C. Rentschler, D. E. Henry and K. O. Smith.

Rev. Sci. Inst., *Vol.* 3, *No.* 12, *pp.* 794,802, *December*, 1932.

A method is described for preparing photo-electric cells of any metal which can be made in wire form. A simple method is described for making photo-electric cells sensitive to radiations of wavelength 2,500 A.U. or shorter, without the use of quartz. Also a design is given for constructing cells in quartz where it is essential to use the more transparent container. F. J. C. B.

63. A Mechanical Aid to the Analysis of Complex Spectra. George R. Harrison.

Rev. Sci. Inst., *Vol.* 3, *No.* 12, *pp.* 753-759, *December*, 1932.

A simple machine is described which quickly and automatically records on a chart the wave-number intervals between each line in a spectrum. Provision can also be made for determining the approximate intensities of the lines. F. J. C. B.

III.—SOURCES OF LIGHT.

64. The Choice of an Enlarging Illuminant. Arthur Lewis.

Brit. J. Photog., *Vol. LXXIX*, *No.* 3,785, *p.* 696, *November*, 1932.

A review of the many types of light-sources now available for photographic enlarging purposes. F. J. C. B.

65. Sodium Gas Discharge Lamps at Schlieren. A. Wertli.

Bulletin de l'Association Suisse des Electriciens, *No.* 23, *November*, 1932.

The "Philora" lamp used on this experimental work is fully described, its physiological effect discussed, the installation and fittings detailed, and the results secured stated. J. E.

66. New Studies of the Arc Discharges. J. L. Myer.

El. Engineering, 52, *p.* 122, *February*, 1933.

An abstract of a paper published at the winter session of the A.I.E.E. The article describes the results of experiments with attempts to relate the data with the theory of arc discharge. S. S. B.

IV.—LIGHTING EQUIPMENT.

67. Tests of Illuminating Glass. R. G. Weigel.

Licht und Lampe, *No.* 25, *December 8th*, 1932.

The products of nineteen German glass works consisting of 300 specimens of opaque and coated glass and about 80 of matt glass were tested, by the Luminotechnical Institute at Karlsruhe, for transmission, reflection, absorption, light distribution and dispersion. Results, for the glasses as submitted and as modified by subsequent surface treatment, are presented. J. E.

68. Combination Luminaries. Anon.

Frank. Inst. J., 215, *p.* 220, *February*, 1933.

A brief note on lighting fittings combining tungsten and mercury-vapour lamps. S. S. B.

69. Electron Tubes in Radio City Theatres. Anon.
Electronics, 6, *p.* 32, *February*, 1933.

The article describes the lighting-control equipment of two theatres in Radio City, U.S.A., which is accomplished by electronic devices. S. S. B.

70. Burnt-out Indicator. H. G. Schiller.
Light, 2, *No.* 10, *p.* 29, *Year end*, 1932.

Details, with a photograph, are given of a device used to locate rapidly a lamp failure in series burning on traction circuits. Each lamp is fitted with an adaptor of special construction. When a lamp fails a small neon indicator glows, while the circuit is maintained by the insertion of a resistance.
C. A. M.

71. A Novel Optical Screen for Classroom Demonstrations. Joseph H. Howey.
Rev. Sci. Inst., *Vol.* 3, *No.* 12, *pp.* 777-781, *December*, 1932.

A new optical screen for making rays of light visible to large lecture classes is described.
F. J. C. B.

72. The Technical Basis of Projection in Illumination. H. Schering.
Licht u. Lampe, *No.* 2, *p.* 29, 1933; *No.* 3, *p.* 57, 1933; *No.* 4, *p.* 93, 1933.

The author deals with lantern, cinematograph and epi-projection separately. He relates the influences of the various factors (e.g., objective aperture and size of the light-source) for the different types of projection. Some data are given of the brightness of various projection light-sources and of the efficiency of lantern and cinematograph projection with the use of different condensers and auxiliary mirrors. E. S. B-S.

V.—APPLICATIONS OF LIGHT.

73. Standards of School Lighting with Suggested Requirements for a School Lighting Code.
Am. Illum. Eng. Soc., *Trans.*, 28, *pp.* 21-56, *January*, 1933.

Parts I, II, III and IV are devoted to the following aspects of the lighting problem respectively: Lighting and vision, what constitutes good lighting, the natural lighting of schoolrooms, and artificial lighting. In these sections the problems are described and recommendations are made, and in Part V regulations for a school-lighting code are given. G. H. W.

74. Special Lighting Applications for Industrial Processes. J. M. Ketch, W. Sturrock and K. Staley.
Am. Illum. Eng. Soc., *Trans.*, 28, *pp.* 57-79, *January*, 1933.

The paper discusses several lighting installations where special design features were necessary in order to meet the requirements. These special applications deal particularly with inspection processes that are found in industrial plants where unusual visual tasks are encountered. Ten lighting principles which have specific application to these problems have been classified and, where possible, illustrated with photographs of actual installations.
G. H. W.

75. Light and Architecture.
Am. Illum. Eng. Soc., *Trans.*, 28, *pp.* 8-20, *January*, 1933.

Some observations are made on present-day lighting in Paris, and illustrated descriptions of eight modern lighting installations in America are given.
G. H. W.

76. Assessing Illuminated Areas on the Basis of Visual Adaptability. J. Ondraek.
Die Lichttechnik, *No.* 5, *pp.* 33-36, *September 25th*, 1933.

In factories the intensity of illumination to which the eye is subjected plays an important rôle in production costs and quality. The author considers that the quotient of the average luminous intensities of the most and least brilliantly lighted places on which the worker's eye gazes is a valuable means of determining the suitability of an installation to the grade of work performed, and advocates, on the basis of information given, this subject should be further investigated from practical examples in different industries. J. E.

77. Hotel and Theatre Lighting. Anon.
Elect., 110, *p.* 171, *February 3rd*, 1933; *p.* 201, *February 10th*, 1933.

Details, with photographs, are given of the complete lighting equipment of the new Plaza Theatre, Rugby, and of a new lighting installation at the Grand Hotel, Birmingham. C. A. M.

78. Progress during 1932. H. W. Richardson.
G.E.C. Journal, 4, *pp.* 24-32. *February*, 1933.

The section dealing with lamps and illumination includes reference to a new built-in cut-out for series burning lamps. A number of recent public lighting and floodlighting installations are described with photographs, including those employing cold-cathode discharge tubes Results of the development of refracting and diffusing glassware for general illumination problems are also dealt with.
C. A. M.

79. Sells Floodlighting by Demonstration. Anon.
El. World, 101, *p.* 66, *January 14th*, 1933.

Describes a motor-lorry which is used by the Central Illinois Light Company for the demonstration of floodlighting. Figures are given showing the success of this method of advertising.
W. C. M. W.

80. Photo-cells in Industry. Anon.
El. World, 100, *pp.* 620-622, *November 5th*, 1932.

The substance of a paper given by Mr. O. H. Caldwell before the New York Electrical Society is given in shortened form. The applications of photo-cell control to various industrial processes are discussed. W. C. M. W.

81. Photography by Electric Light. P. Abgrall.
Lux, *No.* 9, *pp.* 128-131, *November*, 1932.

The utilization of over-incandesced gasfilled lamps for short time exposures, in amateur and professional studios or rooms, is comprehensively dealt with and illustrated, technical data being given together with the results secured with different makes of lamp. J. E.

82. Indoor Film and General Photography for Amateurs. M. Choix.
Lux, *No.* 9, *pp.* 132-133, *November*, 1932.

A short article embracing much practical experience usefully detailed for those desiring to produce films indoors by artificial light, dealing with the light-sources and their disposition, as well as with the properties of the film emulsion. J. E.

83. A Thyratron-controlled Demonstration Show Window. L. D. Wright.
Light, 2, *No.* 10, *pp.* 22-23, *Year end*, 1932.

Particulars, with photographs, are given of the lighting equipment of two demonstration show windows of the State Electricity Commission in Melbourne, Australia, in which thyratron control is employed for dimming and colour changing.
C. A. M.

Brompton and Kensington Electricity Supply Co. Ltd.
An Attractive Series of Showrooms

At the invitation of Mr. R. S. Downe, the general manager and engineer of the Brompton and Kensington Electricity Supply Co. Ltd., the writer has paid a visit to the well-equipped showrooms in the Earl's Court Road, opened about a year ago, where a special demonstration week was recently arranged. The accompanying illustration shows the impressive consumers' lounge, in which films and chromatic lighting and other demonstrations are frequently given. A feature here is the colour lighting from panels just below the roof and from the central domes. Throughout the building general use is made of indirect methods, one pleasing feature being the lighting up of the panels in the entrance hall, where the inscription above the counter commemorates the discovery of magnetic induction.

A View of the luxurious Consumers' Lounge.

The display windows are fully equipped with spotlights and colour-changing devices, and throughout the building there are numerous examples of decorative lighting—such as stained-glass windows lighted from behind to give a daylight effect. A feature is the electrically equipped kitchen, where visitors may experiment for themselves, and the "heating room" furnishing hot water for office heating.

The company is in many respects an interesting one, not merely for its long record since its early days as the "House-to-house Electric Light Supply Company," but for the fact that its load is almost exclusively a residential one in a district where there are few opportunities for building expansion. Its methods, therefore, furnish an interesting example of what can be done under such conditions, and we do not doubt that the ingenuity and enterprise shown in the equipment of these attractive showrooms has been well repaid.

Architects' Conference on Lighting

The fortnightly conferences for architects on electric lighting, announced in our last issue,* are now in full swing at the E.L.M.A. Lighting Service Bureau, and according to all accounts are again proving very successful.

The opening address, on "Lighting Principles," delivered by Mr. W. J. Jones on January 18th, was devoted to eight main points of importance in connection with good lighting, namely, contrast, effective illumination, amount of illumination required, avoidance of glare, light-distribution, reflection from walls and ceilings, effect of proportions of room and maintenance. Most of these points were illustrated by telling examples or by demonstrations. The discussion was opened by Mr. Atkinson, F.R.I.B.A., who cordially approved the plea for fuller co-operation on the part of architects and engineers. One of the speakers, Mr. Thorpe, created amusement by the statement that the illumination in the cloakroom at his club only attained 0.1 foot-candle—small wonder that umbrellas were occasionally removed by mistake!

Mr. R. O. Ackerley, who, on February 1st, dealt with "Domestic Lighting," distinguished between (1) utilitarian lighting, (2) purely decorative lighting, and (3) "amenity lighting"—the latter a combination of (1) and (2). He emphasized the importance of flexibility and of provisions for extensions, and finally remarked on the need for adequately illuminated house-numbers in residential areas. A suitable arrangement, enabling the name or number to be clearly revealed at night, would not cost more than £1 to install, and only a shilling or two a year to run. The discussion on this occasion was opened by Mr. C. Lovett Gill, F.R.I.B.A.

The third address in the series, by Mr. H. C. Wheat, on February 15th, dealt with "The Lighting of Commercial Buildings." After detailing the various methods of lighting offices and illustrating the most important principles, Mr. Wheat quoted some figures to illustrate the very moderate cost of adequate illumination in modern business premises in comparison with other standing charges.

* *Illum. Eng.*, February 13th, 1933, p. 30.

Automatic Control of Lighting in the National Portrait Gallery

Another application of Osram photo-cells of an interesting character is now operating at the National Portrait Gallery in Trafalgar Square, London. It is designed to control illumination in connection with the famous picture of War Statesmen by Sir James Guthrie.

The fluctuations by daylight, particularly in winter time, greatly impede the inspection of works of art in many art galleries, but by a simple expedient this handicap has been overcome in respect to the above-mentioned picture, on which a good deal of attention is just now being focussed.

A photo-cell amplifier operates when daylight falls below a specified intensity, and by closing a contactor switches on four 300-watt lamps to illuminate the picture.

Customer: "What about these cheap lamps I see advertised? Wouldn't it pay me to use them?"

Contractor: "No more than it would pay me to sell them. *You* would save a few pence in first cost, but would lose heavily on current consumption and lamp replacements. *I* might sell a few more lamps to begin with, but would quickly lose both the goodwill and the orders of customers to whom I had supplied low-grade, unreliable lamps."

Customer: "Well! *You* should know. I'll take Mazda Lamps again. They have always given excellent service."

USE MAZDA LAMPS

WITH THE WONDERFUL NON-SAG FILAMENT

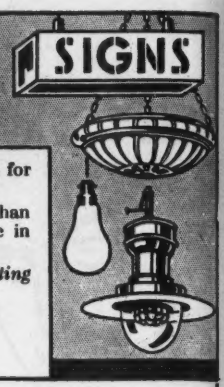
B T-H

MADE IN ENGLAND ENTIRELY FROM BRITISH MATERIALS.

3446

THE BRITISH THOMSON-HOUSTON COMPANY, LTD.

WHERE TO BUY
A DIRECTORY OF LIGHTING EQUIPMENT



We invite applications for spaces in this new section of the journal. Particulars of terms for each space (approx. 1 inch deep and 3¼ inches wide) are given below.

These terms are equivalent to **half our ordinary advertising rates**, but not less than 12 successive monthly insertions can be accepted on this basis, and amounts are payable in advance.

Payment for an advertisement in this section entitles the advertiser to receive *The Illuminating Engineer* during the period of the contract.

Terms: 12 Successive Monthly Insertions	£3 10 0	}	Payable
24 ,, ,, ,,	£6 0 0	}	in
36 ,, ,, ,,	£8 10 0	}	Advance

(1)

PHOTOMETERS

ALEXANDER WRIGHT & CO., LTD.,
1, Westminster Palace Gardens, Artillery Row, Victoria Street, LONDON, S.W.1.

(2)

ALLOM BROTHERS LTD.
15, GEORGE ST., HANOVER SQ., LONDON, W.1
Specialists in the Science of Modern Lighting, including :—
Theatres and Public Halls. Tennis and Racquet Courts.
Pictures and Picture Galleries. Floodlighting, etc.
Decorative Fittings in Glass and Metal.

(3)

You get the benefit of over twenty years' world-wide experience in the science of Commercial and Industrial Illumination when you specify lighting planned by

BENJAMIN

The Benjamin Electric Ltd., Tottenham, N.17

(4)

"LINOLITE" STRIP REFLECTORS
For showcase, shopwindows, cornice, facia, architectural lighting, etc.
Sole Manufacturers :—
A. W. BEUTTELL LTD.
96, VICTORIA ST., LONDON, S.W.1

(5)

BROMFORD
Seamless Steel Lighting Standards. Traffic Signals. Guard Pillars
for all requirements
BROMFORD TUBE CO., LTD., ASTON, BIRMINGHAM

(6)

Specialists in
ARCHITECTURAL ILLUMINATION AND DESIGNS
DRAKE & GORHAM LTD.
36, GROSVENOR GARDENS, LONDON, S.W.1
Manchester, Glasgow, Exeter. and Winchester

(7)

ELECTRICITY SERVICES LTD.
Electrical Engineers
Sole Proprietors and Patentees of
THE "TYPERLITE" ADJUSTABLE LOCAL LIGHTING UNITS
Write for Price Lists : **86, CANNON ST., LONDON, E.C.4**
(Mansion House 5294 3 lines)

(8)

Engineering & Lighting Equipment Co. Ltd.
SPHERE WORKS, St. Albans, Herts.
Manufacturers of :—
Street and Industrial Lighting Fitttings and Equipment.
Specialists for over 30 years. Send for new Cat. No. 12.

(9)

"ESLA"
BI-MULTI AND MULTIPLANE REFLECTORS
Lanterns, Brackets, Columns, Switch and Fuse Boxes etc., FOR STREET LIGHTING
The Electric Street Lighting Apparatus Co.
The Foundry, Canterbury

(10)

G.V.D. ILLUMINATORS
Controlled Diffusion and Distribution of Light.
Industrial and Architectural Lighting.
Aldwych House, LONDON, W.C.2.

(11)

HAILWOOD & ACKROYD LTD.
BEACON WORKS, MORLEY, Near LEEDS
Sole makers of "HAILWARE" British-made Illuminating Glassware and Fittings, Traffic Globes and Signs, Island Columns and Footlights.
Offices and Showrooms at :—
71/75, New Oxford St., London, W.C.1. 314a, St. Vincent St., Glasgow
Carlton House, 28, High Street, Birmingham

(12)

Specify
HOLOPHANE
(*Scientific Illumination*)
ELVERTON ST., LONDON, S.W.
for
STREET CHURCH INDUSTRIAL
CINEMA FLOOD SCHOOL, Etc.

(13)

KANDEM ELECTRICAL LTD.
(Late KORTING & MATHIESEN ELECTRICAL LTD.)
711 and 715, FULHAM ROAD, LONDON, S.W.6
Scientifically designed Incandescent Lighting Equipment for
CHURCHES, SCHOOLS, FACTORIES, STORES, STREETS, FILM AND PHOTOGRAPHIC STUDIOS.
Modern Arc Lamps for Street Lighting. Silent Arcs for Film and Photographic Studios.

(14)

RADIOVISOR PARENT LTD.
28, LITTLE RUSSELL STREET, LONDON, W.C.1
Specialists in Light Sensitive Work
AUTOMATIC CONTROL of STREET and FACTORY LIGHTING
Increasingly in demand as the most efficient and economical control
Phone : Holborn 2986

(15)

SIEMENS
38-39, UPPER THAMES STREET, LONDON, E.C.4.
ELECTRIC LAMPS of all types. ELECTRIC LIGHT FITTINGS. FLOODLIGHTING APPARATUS. SHOP-WINDOW LIGHTING EQUIPMENT. STORE LIGHTING. INDUSTRIAL LIGHTING. CINEMA LIGHTING. ELECTRIC SIGNS, Etc.

(16)

STRAND ELECTRIC
AND ENGINEERING CO. LTD.
19-24, FLORAL STREET, LONDON, W.C.2
Specialists in Modern Theatrical Lighting
Manufacturers of "Sunray" Lighting Equipment
Electrical Installation Contractors. Lighting Schemes for
Theatres Floodlighting Exhibitions Cinemas Pageants
Shop Windows Dress Parades Ballrooms Tea Lounges

(17)

For every type of GAS LIGHTING

SUGG WESTMINSTER

When you want the best!
Chapter St., S.W.1

(18)

TROUGHTON & YOUNG LTD.
ELECTRICAL ENGINEERS
143, KNIGHTSBRIDGE, LONDON, S.W.1
TELEPHONE : KENSINGTON 8881 (5 LINES)
MODERN LIGHTING FITTINGS

(19)
WARDLE ENGINEERING Co. LTD.
OLD TRAFFORD, MANCHESTER
STREET LIGHTING EQUIPMENT. TRAFFIC SIGNALS.
PRISMAT BULKHEAD FITTINGS. FLOODLIGHT PROJECTORS.
WORKSLITE REFLECTORS. WARDELYTE GLASSWARE.

(20)
"THE FITTINGS THAT IMPROVE WITH AGE"
WOODFYT
(WOOD ELECTRIC FITTINGS)
10a, NEWMAN STREET, W.1
(Museum 7325)
Catalogue sent on application

Sheffield Illumination Society

A most interesting visit was made to the Sheffield City Hall on January 26th by members and friends of the Sheffield Illumination Society. The party was told that the large hall (Oval Hall) seats 3,000 people and is approximately 130 ft. long by 100 ft. wide. There is provision over the orchestra for a concealed Angelic Choir, the sound coming through openings in the coffered ceiling. Provision is also made for a chorus under the platform. This hall is equipped for film projection, and contains a very fine organ, built by Messrs. Henry Willis & Son Ltd.

Adjoining the Oval Hall is the Memorial Hall, dedicated to the men of Sheffield who lost their lives in the war. There is seating accommodation for over 500 people. The middle, and largest, of the three lower halls, occupying the whole area of the building, is the dance room, and is splendidly equipped for the purpose. The ventilation system was another notable feature, and the air-washing plant and arrangements for heating the building were explained by the guide.

Credalux
Industrial, Commercial & Street Lighting Shopwindow

REFLECTOR FITTINGS
SCIENTIFICALLY DESIGNED
SIMPLEX ELECTRIC CO. LTD.
Head Office: 159, GREAT CHARLES STREET, BIRMINGHAM, 3

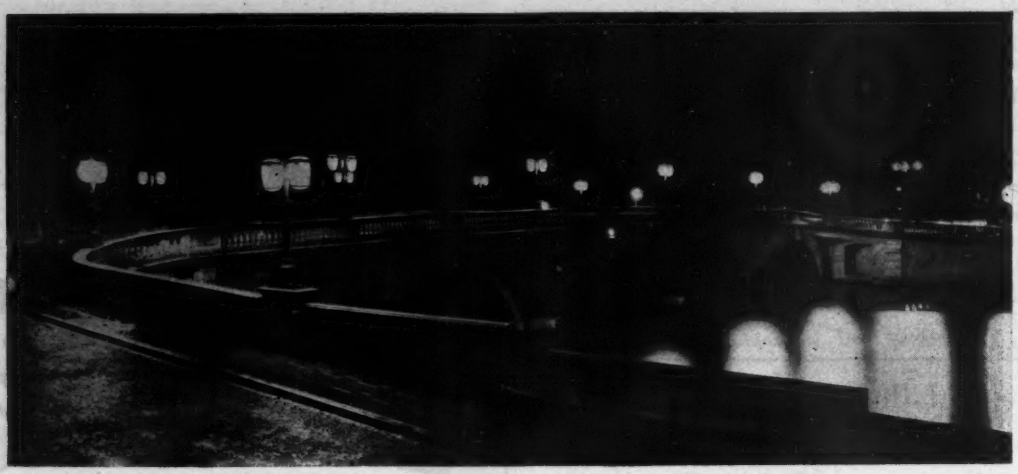
London Electric Firm, Liverpool.
Reduction Gears, Searchlights—*largest to smallest in the world (Display Types, Sale or Hire)*, Mirrors, Lenses, Carbons, Floodlights, Flexible Couplings, Lamp Lowering and Suspension Gear, Wire Ropes

Headlights, Street Lamps, Signal Lamps, Flashing Shutters, Cable Drums, Winches, Guide Pulleys, Poles, Brackets, Irons, Kettles, Fires, etc.
On War Office, Admiralty, Air Ministry, Post Office, etc., etc., Lists

Street Lighting . . . automatic control with negligible maintenance!
Particulars of "Contactor System" from
BROOKHIRST SWITCHGEAR LTD.,— CHESTER.

BUY 100% LIGHT
Your customer buys lamps to give light.
In buying CRYSELCO Lamps he gets the maximum of light for the electricity paid for.
So-called "cheap" lamps often give less than 100% light, sometimes only 80% of the light you get from CRYSELCO Lamps.
This is not economy as the cost of the lamp is negligible compared with the electricity account.
Order your stocks to-day or send for Price Lists and Terms.

TELL THEM TO FIT
CRYSELCO GASFILLED LAMPS
AND "SEE" THE DIFFERENCE
HOME BRANCHES.
BIRMINGHAM: Albion Buildings, 4, Vesey Street. 'Grams: "Cryselco, Birmingham." 'Phone: Aston Cross 1523.
BRIGHTON: 59, Ship St. 'Grams: "Cryselco, Brighton." 'Phone: Brighton 5512.
BRISTOL: Paramount Chambers, Mitchell Lane, Victoria Street. 'Grams: "Cryselco, Bristol." Phone Bristol 24069.
CARDIFF: 27, Edwards Terrace. 'Grams: "Cryselco, Cardiff." Phone: Cardiff 1169.
GLASGOW: 172, Bath St. 'Grams: "Cryselco" Glasgow." Phone: Douglas 577.
LEEDS: 43, York Place. 'Grams "Cryselco, Leeds." 'Phone: Leeds 27866
LIVERPOOL: 22, Sir Thomas St. 'Grams: "Cryselco, Liverpool." 'Phone: Bank 5410-11.
LONDON SALES OFFICE & STORES: Bartlett's Buildings, Holborn Circus, E.C.4 'Grams: "Cryselco Lamps, London." 'Phone: Central 2942; and at Thanet House, 231-2 Strand, W.C.2. 'Grams: "Cryselco, Estrand, London." Phones: Central 3016-7-8
MANCHESTER: 11, Albert Square. Trade Counter: 52, Brazennose Street. Grams: "Cryselco, Manchester." 'Phone: Blackfriars 4971-2.
CRYSELCO, LTD., KEMPSTON WORKS, BEDFORD.
'Phones—Bedford 3277 & 3278 'Grams—"Cryselco, Kempston, Bedford."
MADE IN ENGLAND



We reproduce above a pleasing view by night of Worcester Bridge, illuminated by specially designed G.E.C. lanterns equipped with Wembley refractors and Osram lamps. This reconstructed bridge over the River Severn at Worcester was recently opened by H.R.H. the Prince of Wales, and is shown to evident advantage. The decorative lanterns are fitted with 200-watt lamps at the approaches and 150-watt lamps for the actual bridge units.

Street Lighting with Gas

A new catalogue just issued by Messrs. Wm. Sugg & Co. Ltd. contains in all 111 pages and incorporates various new features. The familiar forms of standard lamps (Little, Rochester, Windsor, etc.), are illustrated, and at the end of the catalogue an enterprising departure is made by including a table showing how such lamps may be selected and distributed in order to meet the requirements of various classes in the British Standard Specification.

Another new feature is the prominence given to directional steel reflectors, of which various forms are illustrated, e.g., the lateral multiple-face models designed for use with cluster lamps and the "Multi-ray" types mounted under the mantles. There is no doubt that such devices add considerably to the distributing powers of public lamps, and their use well deserves study, especially when the lamps have to be spaced at relatively great intervals.

Yet another feature is the series of lamps for special purposes, amongst which we may single out the suspension Rochester lamp, which can be attached to a lamp-post to give a supplementary beam to illuminate an officer on point-duty, and the upright and centrally suspended Rochester lamps with concentrating shades which serve a similar purpose.

One observes with approval that the mean lower hemispherical candle-power of the principal lamps and fittings, as well as the maximum value, is stated, and that polar curves of light-distribution from representative lamps are included.

At the end of the catalogue is a series of photographs of important street-lighting installations at home and abroad.

Mr. H. V. Wynne Roberts

We learn with regret of the death, on February 4th, of Mr. H. V. Wynne Roberts, at the early age of 49. Born in 1883, he joined the General Electric Co. Ltd. in 1901, becoming a director in 1929. Apart from his successful work as sales manager of the G.E.C., he was associated with the B.E.A.M.A., the E.D.A., the E.A.W., and other organizations and his sterling qualities won him the esteem of many friends in the electrical industry.

New Catalogues of Electric Fittings

During the past month we have received several novel and interesting lists of electric fittings, to which we hope to make fuller reference later.

First we must mention an attractively got up and highly original list from Troughton & Young ("Modern Decorative Lighting"), in which a very great variety of architectural lighting fittings is illustrated. Many of these embody the now familiar diffusing tubes, others luminous discs, plates and cylinders, the materials throughout being chromium-plated metalwork and diffusing glassware.

Another well-produced and comprehensive catalogue on standard lines is that issued by Engineering & Lighting Equipment Ltd. This features several new types of fittings. The S.L.R. dust-proof units with plate-glass front (preventing any possible fall of material in the event of a lamp breaking) should meet a want, and the "Bulklite" prismatic bulkhead fittings is a compact and effective device.

Lastly we should mention a neatly assembled series of leaflets illustrating the G.V.D. system. Several of the novel lighting units mentioned therein have been recently illustrated in this journal.

Contracts Closed

The following contracts are announced:—

THE GENERAL ELECTRIC CO. LTD.:—

Booth Steamship Co.; Coast Lines Ltd.; T. & J. Harrison; and James Moss & Co.; for Osram and Robertson electric lamps.

Bibby Line; for Osram electric lamps.

Great Southern Railways Co. of Ireland; twelve months' contract for Osram train-lighting lamps.

London Electric Railway; for 20,000 Osram lamps.

General Post Office; for 150,000 Robertson carbon-filament telephone switchboard lamps.

Borough of Dunstable; twelve months' contract for Osram lamps for street lighting.

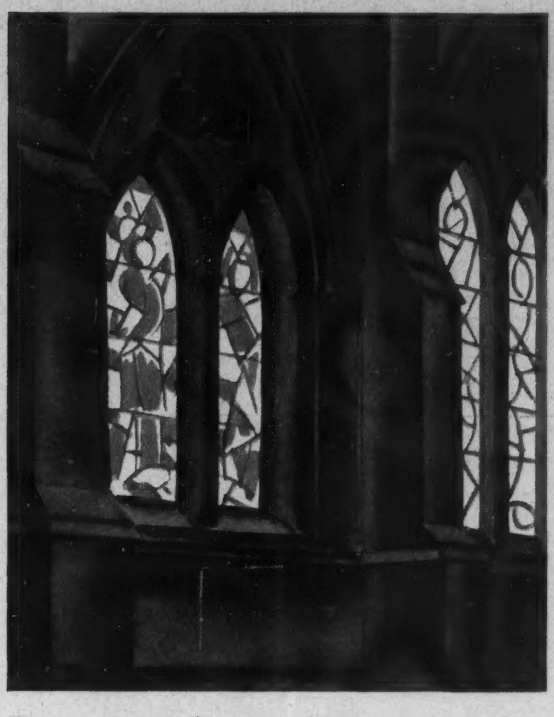
SIEMENS ELECTRIC LAMPS AND SUPPLIES LTD:—

Booth Steamship Co. Ltd.; for twelve months' supply of Siemens electric lamps.

London Midland & Scottish Railway Co.; electric lamp requirements for twelve months ending December 31st, 1933.

Dublin United Tramways Co. (1896) *Ltd.;* for the supply of omnibus lamps and electrical accessories during the year 1933.

The lighting is better and the draughts are gone



There is a certain church in the provinces whose congregation had, until lately, complained for years of intolerable draughts. Called into consultation, the local gas company's engineer prescribed an inexpensive new lighting system. Six clusters, each of twenty small burners, distant-controlled, giving 6000 candlepower, were suspended in rows some fifteen feet below the roof principals and forty feet from the floor. Thanks to the gentle warmth of gas lighting, *the draughts disappeared at once.*

Since gas, the most reliable of illuminants, ventilates even as it illuminates, gas lighting is eminently suitable for all buildings—and galleried buildings in particular—in which large numbers of people assemble. Every building presents an individual problem. Will you remember that the advice and help of the gas industry's experts are always at your disposal? The Secretary of the B.C.G.A. will be glad to arrange for any necessary consultations.

PLAN GAS FOR LIGHTING and leave nothing to chance

THE BRITISH COMMERCIAL GAS ASSOCIATION, 28 GROSVENOR GARDENS, LONDON, S.W.1

THE LONDON POWER COMPANY

Specify

HOLOPHANE LIGHTING

for the New Battersea Power Station

A General View of the Turbine House lighted by 1,000 Holophane Heavy Duty Units
(Night Photograph)

The advisability of entrusting the lighting of such an important undertaking to experts is fully realised by Messrs. The London Power Company. The collaboration of the chief Electrical and Erection Departments with Engineers of the Holophane Company has resulted in an installation which will take pride of place amongst Power Station undertakings throughout the British Isles.

Holophane, the pioneers of scientific illumination for 40 years, will gladly submit specifications or send you specially prepared technical booklets on all phases of lighting.

A beautifully illustrated and practical booklet entitled "Scientific Industrial Lighting" sent free on request.

HOLOPHANE

1, ELVERTON ST., VINCENT SQ., LONDON, S.W.1

Telegrams—"Holophane, Sowest, London." Telephone—Victoria 8062 (3 lines)